(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 June 2005 (02.06.2005)

PCT

(10) International Publication Number
WO 2005/050751 A2

(51) International Patent Classification[7]: H01L 51/10, 23/26

(21) International Application Number: PCT/US2004/037597

(22) International Filing Date: 10 November 2004 (10.11.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/519,139 12 November 2003 (12.11.2003) US
60/619,222 15 October 2004 (15.10.2004) US

(71) Applicant (*for all designated States except US*): **E.I. DUPONT DE NEMOURS AND COMPANY** [US/US]; 1007 MARKET STREET, WILMINGTON, DE 19898 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **TREMEL, James, Daniel** [US/US]; 2825 Foothill Road, Santa Barbara, CA 93105 (US). **HUBERT, Matthew, Dewey** [US/US]; 167 Southwell Road, Columbia, SC 29210 (US).

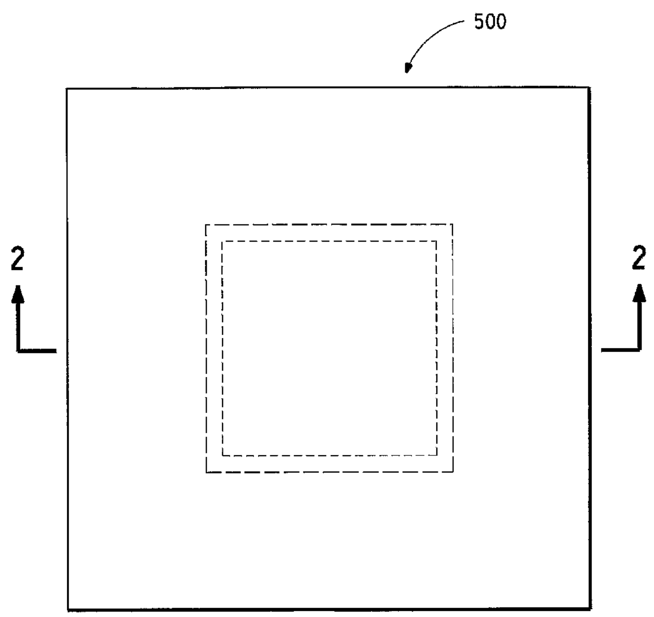
(74) Agent: **CAPRIA, Mary, Ann**; E. I. Du Pont De Nemours and Company, Legal Patent Records Center, 4417 Lancaster Pike, Wilmington, DE 19805 (US).

(81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,

[Continued on next page]

(54) **Title:** ENCAPSULATION ASSEMBLY FOR ELECTRONIC DEVICES



(57) **Abstract:** Describe are encapsulation assemblies useful for electronic device, having a substrate and an electrically active area, the encapsulation assembly comprising a barrier sheet; and a barrier structure that extends from the sheet, wherein the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon. In some embodiments, the barrier structure is designed to be used with adhesives to bond the encapsulation assembly to the electronic device. Gettering materials may be optionally used.

WO 2005/050751 A2

FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TITLE

ENCAPSULATION ASSEMBLY FOR ELECTRONIC DEVICES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Application No. 60/519,139 filed November 12, 2003, which is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates in general to a encapsulation assemblies for electronic devices to prevent exposure of the electronic devices to contaminants.

BACKGROUND INFORMATION

Many electronic devices require protection from moisture, and in some cases oxygen, hydrogen, and/or organic vapors to prevent various types of degradation. Such devices include organic light-emitting diode ("OLED") devices based on polymer or small molecule construction, microelectronic devices based on silicon IC technology, and MEMS devices based on silicon micro-machining. Exposure to the atmosphere can cause cathode degradation by oxide or hydroxide formation (leading to decreased performance/luminance), corrosion or stiction, respectively. Hermetic packaging and sealing technologies exist that address this problem, but these have limitations in performance lifetime and manufacturability, leading to high costs.

SUMMARY OF THE INVENTION

Provided is an encapsulation assembly for an electronic device, having a substrate and an active area, the encapsulation assembly comprising:

a barrier sheet; and

a barrier structure that extends from the sheet, wherein:

the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon when used in conjunction with an adhesive to bond the encapsulation assembly to the device substrate; and wherein the barrier structure is not fused to the device substrate. In one embodiment, the barrier structure is configured so as to avoid direct contact with the electronic device substrate when the device is bonded to encapsulation assembly.

Also provided is an encapsulation assembly for an electronic device, having a substrate, which further has a sealing structure and an active area, the encapsulation assembly comprising:

a barrier sheet having a substantially flat surface; and

a barrier structure that extends from the flat surface, wherein:

the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon; and wherein the barrier structure is configured to engage with the sealing structure on the device substrate.

In the alternative, provided is an encapsulation assembly for an electronic device, having a substrate which further has a barrier structure extending from the substrate and outside of an active area, the encapsulation assembly comprising a barrier sheet having a substantially flat surface and a sealing structure; and wherein the sealing structure is configured to engage with the barrier structure on the device substrate.

In another embodiment, provided is an encapsulation assembly for an electronic device, having a substrate and an active area, the encapsulation assembly comprising:

a barrier sheet; and

a barrier structure that extends from a surface of the sheet, the barrier structure further including a heating element, wherein the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon.

Also provided are electronic devices having such encapsulation assemblies.

The foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as defined in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated by way of example and not limitation in the accompanying figures.

FIG. 1 includes plan view of an electronic device.

FIG. 2 includes a cross-sectional view of the electronic device taken along line 2-2 in FIG. 1.

FIG. 3 includes another cross-section view of the electronic device shown in FIG. 1 and FIG. 2.

FIG. 4 includes another cross-sectional view of the electronic device shown in FIG. 1 through FIG. 3.

FIG. 5 includes a detailed cross-sectional view of the electronic device taken at circle 5 in FIG. 4.

FIG. 6 includes a cross-sectional view of a first alternative embodiment of an electronic device.

FIG. 7 includes another cross-sectional view of the first alternative embodiment of an electronic device.

FIG. 8 includes a cross-sectional view of a second alternative embodiment of an electronic device.

FIG. 9 includes a cross-sectional view of a third alternative embodiment of an electronic device.

FIG. 10 includes a cross-sectional view of a fourth alternative embodiment of an electronic device.

FIG. 11 includes another cross-sectional view of the fourth alternative embodiment of an electronic device shown in FIG. 10.

FIG. 12 includes a cross-sectional view of a fifth alternative embodiment of an electronic device.

FIG. 13 includes a cross-sectional view of a sixth alternative embodiment of an electronic device.

FIG. 14 includes a cross-sectional view of a seventh alternative embodiment of an electronic device.

FIG. 15 includes a cross-sectional view of an eighth alternative embodiment of an electronic device.

FIG. 16 includes a cross-sectional view of a ninth alternative embodiment of an electronic device.

FIG. 17 includes a cross-sectional view of a tenth alternative embodiment of an electronic device.

FIG. 18 includes a cross-sectional view of an eleventh alternative embodiment of an electronic device.

FIG. 19 includes a cross-sectional view of a twelfth alternative embodiment of an electronic device.

FIG. 20 includes a cross-sectional view of a thirteenth alternative embodiment of an electronic device.

FIG. 21 includes another cross-sectional view of the thirteenth alternative embodiment of an electronic device shown in FIG. 20.

FIG. 22 includes a cross-sectional view of a fourteenth alternative embodiment of an electronic device.

FIG. 23 includes a cross-sectional view of a fifteenth alternative embodiment of an electronic device.

FIG. 24 includes a cross-sectional view of a sixteenth alternative embodiment of an electronic device.

FIG. 25 includes a cross-sectional view of a seventeenth alternative embodiment of an electronic device.

FIG. 26 includes a cross-sectional view of an eighteenth alternative embodiment of an electronic device.

FIG. 27 includes a plan view of an encapsulation assembly.

FIG. 28 includes a cross-sectional view of a nineteenth alternative embodiment of an electronic device.

FIG. 29 is a chart illustrating the rate that a Barium film is consumed using a variety of encapsulation techniques.

DETAILED DESCRIPTION

Provided is an encapsulation assembly for an electronic device, having a substrate and an active area, the encapsulation assembly comprising:

a barrier sheet; and

a barrier structure that extends from the sheet, wherein:

the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon when used in conjunction with an adhesive to bond the encapsulation assembly to the device substrate; and wherein the barrier structure is not fused to the device substrate. In one embodiment, the barrier structure is configured so as to avoid direct contact with the electronic device substrate when the device is bonded to encapsulation assembly.

Also provided is an encapsulation assembly for an electronic device, having a substrate, which further has a sealing structure and an active area, the encapsulation assembly comprising:

a barrier sheet having a substantially flat surface; and

a barrier structure that extends from the flat surface, wherein:

the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon; and wherein the barrier structure is configured to engage with the sealing structure on the device substrate.

In the alternative, provided is an encapsulation assembly for an electronic device, having a substrate which further has a barrier structure extending from the substrate and outside of an active area, the encapsulation assembly comprising a barrier sheet having a substantially flat surface and a sealing structure; and wherein the sealing structure is configured to engage with the barrier structure on the device substrate.

In another embodiment, provided is an encapsulation assembly for an electronic device, having a substrate and an active area, the encapsulation assembly comprising:

a barrier sheet; and

a barrier structure that extends from a surface of the sheet, the barrier structure further including a heating element, wherein the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon.

Also provided are electronic devices having such encapsulation assemblies.

The detailed description first addresses Definitions and Clarification of Terms followed by Electronic Device Structures.

1. Definitions and Clarification of Terms

Before addressing details of embodiments described below, some terms are defined or clarified. As used herein, the term "activating," when referring to a radiation-emitting electronic component, is intended to mean providing proper signal(s) to the radiation-emitting electronic component so that radiation at a desired wavelength or spectrum of wavelengths is emitted.

The term "adhesive" is intended to mean a solid or liquid substance that is capable of holding materials by surface attachment. Examples of adhesives include, but are not limited to, materials that are organic and inorganic, such as those using ethylene vinyl acetates, phenolic resins, rubber (natural and synthetic), carboxylic polymers, polyamides, polyimides, styrene-butadiene co-polymers, silicone, epoxy, urethane, acrylic, isocynoate, polyvinyl acetates, polyvinyl alcohols, polybenzimidazole, cement, cyanoacrylate and mixtures and combinations thereof.

The term "ambient conditions" is intended to mean the conditions of a room in which humans are present. For example, the ambient conditions of a clean room within the microelectronics industry can include a temperature of approximately 20 °C, relative humidity of approximately 40%, illumination using fluorescent light (with or without yellow filters), no sunlight (from outdoors), and laminar air flow.

The term "barrier material" is intended to mean a material that substantially prevents the passage of contaminant of concern (e.g., air, oxygen, hydrogen, organic vapors, moisture) therethrough under the conditions to which the final device will likely be exposed. Examples of materials useful to create barrier materials include, but are not limited to, glasses, ceramics, metals, metal oxides, metal nitrides, and combinations thereof.

The term "barrier sheet" is intended to mean a sheet or layer (which can have one or more sublayers or impreganted materials) of barrier material, created using any number of known techniques, including spinning, extruding, molding, hammer, casting, pressing, rolling, calendaring and combinations thereof. In one embodiment, the barrier sheet has permeability less than 10^{-2} g/m^2/24 hr/atm. The barrier sheet can be made of any material that has low permeability to gases and moisture, and is stable at the processing and operating temperatures to which it is exposed. Examples of materials that can be used for the barrier sheet include, but are not limited to, glasses, ceramics, metals, metal oxides, metal nitrides, and combinations thereof.

The term "contaminants" is intented to mean oxygen, air, water, organic vapors or other gaseous materials that can be destructive to sensitive areas of an electronic device, such an the electrically active area of an organic light emitting displays.

The term "ceramic" is intended to mean an inorganic composition, other than glass, which can be heat treated in order to harden the inorganic composition during its manufacture or subsequent use by firing, calcining, sintering, or fusion of at least a portion of the inorganic material, fired clay compositions which form, e.g., porcelain or brick, and refractories.

The term "encapsulation assembly" is intended to mean one or more structures that can be used to cover, enclose, and at least form part of a seal for one or more electronic components within an electrically active area on a substrate from ambient conditions. In conjunction with a substrate that includes one or more electronic components, the encapsulation assembly substantially protects a portion of such electronic component(s)from damage originating from a source external to the electronic device. In one embodiment, a lid, by itself, or in combination with one or more other objects, can form an encapsulation assembly.

The term "complement" is intended to mean either of two structures that mutually completes the other. Two structures that complement each other are similarly shaped, e.g., a triangular rib that fits into a triangular groove.

The term "electronic active area" is intended to mean an area of a substrate, which from a plan view, is occupied by one or more circuits, one or more electronic components, or a combination thereof. For example, in an organic light emitting display, the electrically active area includes the portion of the device having at least one electrode and the light emitting material.

The term "electronic device" is intended to mean a collection of circuits, electronic components, or combinations thereof that collectively, when properly connected and supplied with the appropriate potential(s), performs a function. An electronic device may include or be part of a system. Examples of electronic devices include displays, sensor arrays, computer systems, avionics, automobiles, cellular phones, and many other consumer and industrial electronic products.

The term "engaged" is intended to mean the inserting, interlocking, meshing, placing, receiving, or any combination thereof of a first structure with respect to a second structure.

The term "engagement groove" is intended to mean a channel in a structure (e.g., a housing) and interlocks, meshes with, receives, or any combination thereof another structure (e.g., an engagement rib).

The term "engagement rib" is intended to mean a raised ridge that extends from a workpiece (e.g., a substrate) and is inserted into, interlocks with, meshes with, placed into, or received by another structure (e.g. an engagement groove).

The term "getter material" is intended to mean a material that is used to absorb, adsorb, or chemically tie up one or more undesired materials, such as water, oxygen, hydrogen, organic vapor and mixtures thereof. A getter material can be a solid, paste, liquid, or vapor. One type of gettering material can be used or mixtures or combinations or two or more materials. Examples include any number of materials such an inorganic molecular seives, such as zeolites.

The term "glass" is intended to mean an inorganic composition, which is principally silicon dioxide and may include one or more dopants to change is properties. For example, phosphorous-doped glass can be used to slow or substantially stop mobile ion migration therethrough as compared to undoped glass, and boron-doped glass can be used to lower the flow temperature of such material as compared to undoped glass.

The term "heating element" is intended to mean a structure that generates heat when current flows through the structure or when the structure is exposed to radiation, such as electromagnetic radiation.

The term “hermetic seal” is intended to mean a structure (or combination of structures) that substantially prevents the passage of air, moisture, and other contaminants therethrough at ambient conditions.

The term “keying structure” is intended to mean at least one of complementary structures that can be used to align two parts, e.g., an encapsulation assembly and a housing. One keying structure can engage another keying structure in order to properly align the two parts.

The term "lid" is intended to mean a structure that, by itself or in combination with one or more other objects, can be used to cover, enclose, and forms at least part of a seal for one or more electronic components within an electrically active area of a substrate from ambient conditions.

The term “metallic” is intended to mean containing one or more metals. For example, a metallic coating can include an elemental metal by itself, a clad, an alloy, a plurality of layers of any combination of an elemental metal, a clad, or an alloy, or any combination of the foregoing.

The term “perimeter” is intended to mean a closed curve bounding the central area of the barrier sheet. The perimeter is not limited to any particular geometric shape.

The term "organic electronic device" is intended to mean a device including one or more semiconductor layers or materials. Organic electronic devices include: (1) devices that convert electrical energy into radiation (e.g., a light-emitting diode, light emitting diode display, diode laser, or lighting panel), (2) devices that detect signals through electronic processes (e.g., photodetectors, photoconductive cells, photoresistors, photoswitches, phototransistors, phototubes, infrared (“IR”) detectors, or biosensors), (3) devices that convert radiation into electrical energy (e.g., a photovoltaic device or solar cell), and (4) devices that include one or more electronic components that include one or more organic semiconductor layers (e.g., a transistor or diode).

The term "organic active layer" is intended to mean one or more organic layers, wherein at least one of the organic layers, by itself, or when in contact with a dissimilar material, is capable of forming a rectifying junction.

The term “rectifying junction” is intended to mean a junction within a semiconductor layer or a junction formed by an interface between a semiconductor layer and a dissimilar material, in which charge carriers of one type flow easier in one direction through the junction compared to the opposite direction. A pn junction is an example of a rectifying junction that can be used as a diode.

The term “sealing structure” is intended to mean a complementary structure to the barrier structure, but need not be its complement over a substantial portion of the barrier structure. For each example, a small dip or scoop is sufficient to make a complement to a rounded end portion of a semicircle shaped barrier structure.

The term "structure" is intended to mean one or more patterned layers or members, which by itself or in combination with other patterned layer(s) or member(s), forms a unit that serves an intended purpose.

The term "substrate" is intended to mean a workpiece that can be either rigid or flexible and may be include one or more layers of one or more materials, which can include, but are not limited to, glass, polymer, metal or ceramic materials or combinations thereof.

The term “substantially continuous” is intended to mean that a structure extends without a break and forms a closed geometric element (e.g., triangle, rectangle, circle, loop, irregular shape, etc.).

The term “transparent” is intended to mean the capability to transmit at least seventy percent of radiation at a wavelength or spectrum of wavelengths, e.g., visible light.

As used herein, the terms “comprises,” “comprising,” "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a method, process, article, or apparatus that comprises a list of elements is not necessarily limited only those elements but may include other elements not expressly listed or inherent to such method, process, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

Also, use of the “a” or “an” are employed to describe elements and components of the invention. This is done merely for convenience and to give a general sense of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

2. Electronic Device Structures

Electronic devices that may benefit from the use of the present invention, include, but are not limited, light emitting diodes, organic displays, photovoltaic devices, field emission displays, electrochemcial displays, plasma displays, microelectrical mechanical systems, photonic devices, and other electronic devices using integrated circuits (e.g., including, but not limited to accelerametors, gyroscopes, motion sensors). Thus, the size of the encapsulation assembly can be very small and will vary based on the type of electronic device with which it is being used.

Referring to FIGs. 1 through FIG. 3, an embodiment of an electronic device is illustrated and is generally designated 500. In a particular embodiment, the electronic device is an organic electronic device, but the electronic device can be any electronic device that includes an interior area that requires sealing. As depicted, in FIGs. 1 through 3, the electronic device 500 includes a substrate 502. An electrically active area 504 is established on the substrate 502. Further, the electronic device 500 includes an encapsulation assembly 506. As indicated in FIGs. 2 and 3, the encapsulation assembly 506 includes a surface 508 and a barrier structure 510 that extends from the surface 508 (of a barrier sheet). In a particular embodiment, the barrier structure 510 (made of barrier material) is a glass bead that is deposited or otherwise formed on the surface of the encapsulation assembly 506. Barrier structure 510 has a thickness which is the dimension from which it extends from the barrier sheet at its peak extension. The thickness may be a uniform thickness or may vary depending on the type of barrier sheet, how the barrier sheet and barrier structure are manufactured and the type of device substrate to which the encapsulation assembly will be finally attached. For example, the barrier structure 510 may be created by first depositing the barrier material in one physical forom (such as a paste or fluid) and then treating the material further to create the barrier structure. Or it may be created for example, by other techniques such that the barrier structure is created separately from the barrier sheet or where the barrier sheet 508 and the barrier structure 510 are manufactured together.

FIGs. 2 and 3 also illustrate that the encapsulation assembly 506 can be formed with an interior area 512 on barrier sheet 508 on which one or more layers 514 can be deposited, e.g., on a roof of the interior area 512 (which can be created to have a concave cavity or be substrantially flat) or on the sides of the interior area 512. While this area is shown as part of the shaped barrier sheet, the interior area can be created by the use of the barrier structure element 510 itself if element 510 is thick enough to be higher then the electrically active area to be encapsulated. The layers 514 includes a getter material.

In another particular embodiment, illustrated in FIGs. 4 and 5, the encapsulation assembly 506 can be affixed to the substrate 502 using an adhesive 516 (which may be deposited in more than one location; as shown with 520, an alternative embodiment illustrating a different adhesive usage).

In a particular embodiment, when the encapsulation assembly 506 is affixed to the substrate 502 using the adhesive 516, as portrayed in FIG. 5, the barrier structure 510 and the adhesive 516 establishes a barrier 518 between the encapsulation assembly 506 and the substrate 502 so as to minimize the gap between them. The barrier structure is not fused to both the surface of barrier sheet and the device substrate simultaneously when the device is encapsulated. Further, in a particular embodiment, the barrier structure 510 is no more than one micron from the substrate 502. Accordingly, a permeation route through the adhesive 516 is substantially narrowed and water permeation through the adhesive 516 is substantially reduced.

Referring now to FIGs. 6 and 7, an alternative embodiment, of an electronic device is depicted and is generally designated 1000. As illustrated in FIG. 6, the electronic device 1000 includes a substrate 1002. Further, an electrically active area 1004 is established on the substrate 1002. Moreover, the electronic device 1000 includes an encapsulation assembly 1006. As indicated in FIGs. 6 and 7, the encapsulation assembly 1006 includes a surface 1008 and a barrier structure 1010 that is affixed to the surface 1008. In a particular embodiment, the barrier structure 1010 is a glass bead that is deposited or otherwise formed on the surface of the encapsulation assembly 1006. FIGs 6 and 7 also depict a heating element 1012 that is incorporated into the barrier structure 1010. In a particular embodiment, the heating element 1012 can be selectively heated. In one particular embodiment, the heating element 1012 can be made from a compound having silicon nitride and a refractory metal, such as titanium, tungsten, and tantalum and the heating element 1012 can heat up when subjected to electromagnetic radiation. In another particular embodiment, the heating element can be a resistive wire that heats up when a current is applied to it. In a particular embodiment, a source 1014 is included and the source can selectively expose the heating element 1012 to electromagnetic radiation or electrical current. The heating can take place prior to or in some embodiments, after the assembly of the encapsulation assembly with the electronic device.

During assembly, the barrier structure 1010 can be placed between the substrate 1002 and the encapsulation assembly 1006 such that the barrier structure is juxtaposed with the substrate 1002 and the encapsulation assembly 1006. Further, during assembly, electromagnetic radiation or electrical current can be applied to the heating element 1012 in order to heat the heating element 1012. When the temperature of the heating element 1012 reaches the melting point of the barrier structure 1010, the barrier structure 1010 will melt and fuse with either the substrate 1002 and/or the encapsulation assembly 1006. As such, a hermetic seal can be formed between the substrate 1002 and the encapsulation assembly 1006 by the barrier structure 1010. In a particular embodiment, the application of heat locally to the barrier structure 1010 can substantially prevent the electronic active layer 1004 from being damaged by heat or electromagnetic radiation that would otherwise be required to melt the barrier structure 1010 and fuse it to the substrate 1002 and the encapsulation assembly 1006 as described herein.

FIGs. 6 and 7 further illustrate that the encapsulation assembly 1006 can be formed with an interior area 1016 on which one or more layers 1018 can be deposited, e.g., on a roof of the interior area 1016 or on the sides of the interior area 1016. In a particular embodiment, the layers 1018 include a getter material, e.g., one or more of the getter materials described herein. Although not illustrated in Figures 6-7, it is further envisioned that the barrier structure 1010 may be deposited on the device substrate, with the optional gettering material materials being used in the manner otherwise depicted in the Figures.

Referring to FIG. 8, an alternative embodiment of an electronic device is shown and is designated 1200. FIG. 8 depicts an electronic device 1200 that includes a substrate 1202. Further, an electrically active area 1204 is established on the substrate 1202. Also, the electronic device 1200 includes an encapsulation assembly 1206. As indicated in FIG. 8, the encapsulation assembly 1206 includes a surface 1208 to which a barrier structure 1210 can be affixed. In a particular embodiment, the barrier structure 1210 is a glass bead that can be disposed between the surface 1208 of the encapsulation assembly 1200 and the substrate 1202. FIG. 8 also depicts that a heating element 1212 can be incorporated into the surface 1208 of the encapsulation assembly 1204.

In a particular embodiment, when the barrier structure 1210 is placed between the encapsulation assembly 1204 and the substrate 1202 such that it is juxtaposed with the encapsulation assembly 1204 and the substrate 1202, the heating element 1212 contacts the barrier structure 1210. Further, when the heating element 1212 is heated, the barrier structure 1210 can melt and fuse with the encapsulation assembly 1206 and the substrate in order to establish a hermetic seal around the electrically active area 1204. The localized heating associated with the heating element 1212 substantially reduces damage to the electrically active area 1204 caused by excessive heat.

Referring to FIG. 9, an alternative embodiment of an electronic device is shown and is designated 1300. FIG. 9 depicts an electronic device 1300 that includes a substrate 1302. Further, an electrically active area 1304 is established on the substrate 1302. Also, the electronic device 1300 includes an encapsulation assembly 1306. As indicated in FIG. 9, the encapsulation assembly 1306 includes a surface 1308 to which a barrier structure 1310 can be affixed. In a particular embodiment, the barrier structure 1310 is a glass bead that can be disposed between the surface 1308 of the encapsulation assembly 1300 and the substrate 1302. FIG. 9 also depicts that a heating element 1312 can be incorporated into the substrate 1302 around theelectrically active area 1304.

In a particular embodiment, when the barrier structure 1310 is placed between the encapsulation assembly 1304 and the substrate 1302 such that it is juxtaposed with the encapsulation assembly 1304 and the substrate 1302, the heating element 1312 contacts the barrier structure 1310. Further, when the heating element 1312 is heated, the barrier structure 1310 can melt and fuse with the encapsulation assembly 1306 and the substrate in order to establish a hermetic seal around theelectrically active area 1304.

Referring now to FIG. 10 and FIG. 11, an embodiment of an electronic device is illustrated and is generally designated 1400. As depicted in FIG. 10 and FIG. 11, the electronic device 1400 includes a substrate 1402. Anelectrically active area 1404 is established on the substrate 1402. Further, the electronic device 1400 includes an encapsulation assembly 1406. As indicated in FIG. 10 and FIG. 11, the encapsulation assembly 1406 includes a surface 1408 and a barrier structure 1410 that extends from the surface 1408. In a particular embodiment, the barrier structure 1410 is a glass bead that is integrally formed with the encapsulation assembly 1406. In this example, the barrier structure 1410 can be made from the same or different materials from the materials used in the barrier sheet, and may be created in using a molding technology and may be any desired barrier structure profile desired. In illustration Figure 10, the thickness of barrier structure 1410 varies over the its width. In a particular embodiment, the encapsulation assembly 1406 can be affixed to the substrate 1402 using an adhesive 1412. In a particular embodiment, when the encapsulation assembly 1406 is affixed to the substrate 1402 using the adhesive 1412, as portrayed in FIG. 11, the adhesive 1416 and the barrier structure 1410 establish a hermetic barrier 1418 between the encapsulation assembly 1406 and the substrate 1402.

FIG. 12 illustrates another embodiment of an electronic device that is generally designated 1600. As depicted in FIG. 12, the electronic device 1600 includes a substrate 1602. Anelectrically active area 1604 is established on the substrate 1602. Further, the electronic device 1600 includes an encapsulation assembly 1606. As indicated in FIG. 12, the encapsulation assembly 1606 includes a surface 1608 and a first keying barrier structure 1610 that extends from the surface 1608. In a particular embodiment, the first keying barrier structure 1610 is a substantially continuous engagement rib that extends from the surface 1608 of the encapsulation assembly 1606. Further, the substantially continuous engagement rib is integrally formed with the encapsulation assembly 1606 and has a substantially semicircular cross-section. FIG. 12 also illustrates that the substrate 1608 includes a second keying barrier structure 1612 that is a complement of the first keying barrier structure 1610. Particularly, the second keying structure 1612 is a substantially continuous engagement groove that is correspondingly sized and shaped to receive the first keying barrier structure 1610. In a particular embodiment, when the electronic device 1600 is assembled, the first keying barrier structure 1610 fits into the second keying structure 1612. Further, in a particular embodiment, the encapsulation assembly 1606 can be affixed to the substrate 1602 by heating the area at or around the keying structures

1610, 1612 in order to fuse the keying structures. In another particular embodiment, the first keying barrier structure 1610 can be affixed to the second keying structure 1612 using an adhesive.

FIG. 13 depicts yet another embodiment of an electronic device, designated 1700. In this particular embodiment, the electronic device 1700 includes a substrate 1702 and anelectrically active area 1704 is established on the substrate 1702. Further, the substrate includes a substantially continuous engagement rib 1706 that is integrally formed with the substrate 1702. As illustrated in FIG. 13, the electronic device 1700 includes an encapsulation assembly 1708. FIG. 13 depicts that the encapsulation assembly 1708 includes a surface 1710 and a substantially continuous engagement groove 1712 is formed therein. In a particular embodiment, the engagement rib 1706 and the engagement groove 1712 both have a cross-section that is semi-circular.

FIG. 14 illustrates another embodiment of an electronic device 1800 that has a substantially continuous engagement rib 1802 that extends from an encapsulation assembly 1804 and can fit into a substantially continuous engagement groove 1806 formed in a substrate 1808. As indicated in FIG. 14, the engagement rib 1802 and engagement groove 1806 have a cross-section that is rectangular.

Referring to FIG. 15, still another embodiment of an electronic device 1900 is illustrated and includes a substantially continuous engagement rib 1902 that extends from a substrate 1904 and can fit into a substantially continuous engagement groove 1906 formed in an encapsulation assembly 1908. As indicated in FIG. 15, the engagement rib 1902 and engagement groove 1906 have a cross-section that is rectangular.

FIG. 16 illustrates another embodiment of an electronic device 2000 that has a substantially continuous engagement rib 2002 that extends from an encapsulation assembly 2004 and can fit into a substantially continuous engagement groove 2006 formed in a substrate 2008. As indicated in FIG. 16, the engagement rib 2002 and engagement groove 2006 have a cross-section that is triangular.

Referring to FIG. 17, yet another embodiment of an electronic device 2100 is illustrated and includes a substantially continuous engagement rib 2102 that extends from a substrate 2104 and can fit into a substantially continuous engagement groove 2106 formed in an encapsulation assembly 2108. As indicated in FIG. 17, the engagement rib 2102 and engagement groove 2106 have a cross-section that is triangular.

FIG. 18 illustrates yet still another embodiment of an electronic device 2200 that has a substantially continuous engagement rib 2202 that extends from an encapsulation assembly 2204 and can fit into a substantially continuous engagement groove 2206 formed in a substrate 2208. As indicated in FIG. 18, the engagement rib 2202 and engagement groove 2206 have a cross-section that is frusto-conical.

Referring to FIG. 19, another embodiment of an electronic device 2300 is illustrated and includes a substantially continuous engagement rib 2302 that extends from a substrate 2304 and can fit into a substantially continuous engagement groove 2306 formed in an encapsulation assembly 2308. As indicated in FIG. 19, the engagement rib 2302 and engagement groove 2306 have a cross-section that is frusto-conical.

FIG. 20 and FIG. 21 illustrate yet another embodiment of an electronic device 2400 that has a first substantially continuous engagement rib 2402 that extends from an encapsulation assembly 2404 and can surround a second substantially continuous engagement rib 2406 that extends from a substrate 2408 when the encapsulation assembly 2404 is engaged with the substrate 2408, as shown in FIG. 21. As indicated in FIG. 21, the engagement ribs 2402, 2406 are complementary shaped and have a cross-section that is triangular.

Referring to FIG. 22, another embodiment of an electronic device 2600 is illustrated and includes a substantially continuous engagement rib 2602 that extends from an encapsulation assembly 2604 and can lie substantially within, or be substantially surrounded by, a substantially continuous engagement rib 2606 formed in a substrate 2608. As indicated in FIG. 22, the engagement ribs 2402, 2406 are complementary shaped and have a cross-section that is triangular.

FIG. 23 illustrates still yet another embodiment of an electronic device 2700 that has a first substantially continuous engagement rib 2702 that extends from an encapsulation assembly 2704 and can substantially surround a second substantially continuous engagement rib 2706 that extends from a substrate 2708 when the encapsulation assembly 2704 is engaged with the substrate 2708. As indicated in FIG. 23, the engagement ribs 2702, 2706 are complementary shaped and have a cross-section that is square.

Referring to FIG. 24, another embodiment of an electronic device 2800 is illustrated and includes a substantially continuous engagement rib

2802 that extends from an encapsulation assembly 2804 and can lie substantially within, or be substantially surrounded by, a substantially continuous engagement rib 2806 formed in a substrate 2808. As indicated in FIG. 24, the engagement ribs 2802, 2806 are complementary shaped and have a cross-section that is square.

FIG. 25 illustrates yet another embodiment of an electronic device 2900 that has a first substantially continuous engagement rib 2902 that extends from an encapsulation assembly 2904 and can surround a second substantially continuous engagement rib 2906 that extends from a substrate 2908 when the encapsulation assembly 2904 is engaged with the substrate 2908. As indicated in FIG. 25, the engagement ribs 2902, 2906 are complementary shaped and have a cross-section that is frusto-conical.

Referring to FIG. 26, yet still another embodiment of an electronic device 3000 is illustrated and includes a substantially continuous engagement rib 3002 that extends from an encapsulation assembly 3004 and can lie substantially within, or be substantially surrounded by, a substantially continuous engagement rib 3006 formed in a substrate 3008. As indicated in FIG. 26, the engagement ribs 3002, 3006 are complementary shaped.

Referring now to FIG. 27, an encapsulation assembly, designated 3100, is illustrated in plan view. As indicated in FIG. 27, the encapsulation assembly 3100 includes an interior area 3102 surrounded by a first barrier structure 3104 that extends from a surface of the encapsulation assembly 3100. A second barrier structure 3106 extends from the surface of the encapsulation assembly 3100 around the first barrier structure 3104. In a particular embodiment, each barrier structure 3104, 3106 is an engagement rib, an engagement groove, or a combination thereof. Further, in a particular embodiment, each barrier structure 3104, 3106 can have a cross-section that is semicircular, rectangular, triangular, frusto-conical, or square. As depicted in FIG. 27, a first layer 3108 of getter material can be deposited on the surface of the encapsulation assembly 3102 within the interior area 3102. Also, a second layer 3110 of getter material can be deposited on the surface of the encapsulation assembly 3100 between the interior area 3102 and the first barrier structure 3104. A third layer 3112 of getter material can be deposited on the surface of the encapsulation assembly 3100 between the first barrier structure 3104 and the second barrier structure 3106. Additionally, a fourth layer 3114 of getter material can be deposited on the surface of the encapsulation assembly 3100 around the second barrier structure 3106.

In a particular embodiment, either of the structures 3104, 3106 may be omitted from the construction of the encapsulation assembly 3100. Further, any combination of the layers 3108, 3110, 3112, 3114 of getter material may be omitted from the construction of the encapsulation assembly 3100.

Figure 28 illustrates another embodiment of an encapuslation assembly designated as 4100, illustrated in a cross-section. Interior area 4102 is created by barrier structures 4104, configured to be outside of the device active area 4120. Interior area 4102 includes getter material 4108. The adhesive bonding the encapsulation assembly to the device 4122 is not shown.

From these Figures, it can be appreciated that the barrier structures can be located on the barrier sheet so as to be outside of the electrically active area when the device is encapsulated, and can be on the perimeter edge of the barrier sheet, immediately adjacent to the edge, or more interior from the edge. No spacers are needed to elevate the encapsulation assembly off the substrate of the device, although such spacers may be optionally used if desired.

In each of the embodiments described herein, the seal established between the encapsulation assembly and the device substrate substantially reduces permeation of contaminants through the seal, over encapsulation techniques using adhesive as the primary sealing element while improving manufacturing options over sealing elements where the barrier structure is fused or sintered to both the barrier surface and the device substrate.

In one embodiments using a heating element (see for example, Figure 7, element 1012) a glass containing material may be heated to as to fuse a barrier structure having glass particles to either the barrier sheet, or both the barrier sheet and the device substrate, as desired.

In some embodiments the barrier structure is configured so as to permit contact with the device substrate; in other embodiments the barrier structure is configured to not permit contract; in still other embodiments, the barrier structure is configured to me be no more than 1 micron from the device substrate when encapsulation is completed. In these embodiments, the permeation of containments has been found to be acceptable for many applications, and selection of the adhesive can be made based primarily on factors other than contaminant permeation rate through the adhesive, such as adhesive qualities relating to adhesive strength, UV durability, environmental issues, price, and ease of application to name a few. It has been found that in some embodiments, for example the assembly shown in Figure 28 was used to encapsulate a pixilated monochromic ogranic light emitting diode (using a glass barrier structure, an epoxy adhesive and a zeolte getter material). The results from environmental testing (60 degrees C/ 85% relative humidity and at 85 degrees C and 85% relatively humidity) showed unexpected results: no measureable pixel shrinkage was seen after 1000 hours of exposure under the first set of conditions; and when tested under the second test, less than 5% pixel shrinkage was measured after 1000 hours of exposure to the test conditions.

In one embodiment, the barrier structure is made from a barrier material has a permeability of less than 10^{-2} g/m^2/24 hr/atm. In another embodiment, the barrier structure has permeability less than 10^{-2} g/m^2/24 hr/atm. In one embodiment, the barrier structure has permeability to gases and moisture of less than about 10^{-6} g/m^2/24 hr/atm at room temperatures. In one embodiment, the barrier material is inorganic.

In one embodiment the barrier structure is made from a material that is selected from glasses, ceramics, metals, metal oxides, metal nitrides, and combinations thereof. In one embodiment, the barrier material comprises a non-hermetic base with a coating of barrier material. In one embodiment the barrier structure has the same thickness as that of the electronically active display components of the device (which, for example could correspond to features 504 of Fig. 3, 1004 of Fig. 7, or 1304 of Fig. 9).

In one embodiment, the barrier material is glass and is applied as a glass frit composition. As used herein, the term “glass frit composition” is intended to mean a composition comprising glass powder dispersed in an organic medium. After the glass frit composition is applied to the barrier sheet, it is solidified and densified to form a glass structure. As used herein, the term “solidifying” means drying sufficiently to stabilize the deposited frit composition, such as to prevent unacceptable spreading of the composition to undesired locations or damage caused by storing the surfaces containing solidified frit composition (e.g., by stacking). The term “densifying” means heating or reheating the composition so as to drive off substantially all volatiles, including, but not limited to the liquid medium, and to cause fusing of the glass powder particles and adherence to the surface of the barrier sheet to which it has been applied. Densification can be carried out in an oxidizing or inert atmosphere, such as air, nitrogen or argon, at a temperature and for a time sufficient to volatilize (burn-out) the organic material in the layers of the assemblage and to sinter any glass-containing material in the layers thus, densifying the thick film layer. The permeability of the glass decreases as it is densified. In one embodiment, the glass is fully densified. In one embodiment, densification is determined by the transparency of fired glass, with complete transparency indicating sufficient densification.

Glass frit compositions are well known and many commercial materials are available. In one embodiment, the glass powder comprises, based on weight %, 1-50% SiO_2, 0-80% B_2O_3, 0-90% Bi_2O_3, 0-90% PbO, 0-90% P_2O_5, 0-60% Li_2O, 0-30% Al_2O_3, 0-10% K_2O, 0-10% Na_2O, and 0-30% MO where M is selected from Ba, Sr, Ca, Zn, Cu, Mg and mixtures thereof. The glasses may contain several other oxide constituents. For instance ZrO_2 and GeO_2 may be partially incorporated into the glass structure.

High contents of Pb, Bi or P in glass provide a very low softening point that allow glass frit compositions to densify below 650°C. These glasses are not crystallized during densification, since the elements tend to provide good stability of glass and a high solid solubility for other glass elements.

Other glass modifiers or additives may be added to modify glass properties for better compatibility with a given substrate. For example, the thermal coefficient of expansion ("TCE") of the glass may be controlled by the relative content of other glass components in the low-softening temperature glasses.

Additional examples of glass powders that are suitable include those that comprise at least one of PbO, Al_2O_3, SiO_2, B_2O_3, ZnO, Bi_2O_3, Na_2O, Li_2O, P_2O_5, NaF and CdO, and MO where O is oxygen and M is selected from Ba, Sr, PB, Ca, Zn, Cu, Mg, and mixtures thereof. For example, the glass can comprise 10-90 wt% PbO, 0-20 wt% Al_2O_3, 0-40 wt% SiO_2, 0-15 wt% B_2O_3, 0-15 wt% ZnO, 0-85 wt% Bi_2O_3, 0-10 wt% Na_2O, 0-5 wt% Li_2O, 0-45 wt%, P_2O_5, 0-20 wt% NaF, and 0-10 wt% CdO. The glass can comprise: 0-15 wt% PbO, 0-5 wt% Al_2O_3, 0-20 wt% SiO_2, 0-15 wt% B_2O_3, 0-15 wt% ZnO, 65-85 wt% Bi_2O_3, 0-10 wt% Na_2O, 0-5 wt% Li_2O, 0-29 wt% P_2O_5, 0-20 wt% NaF, and 0-10 wt% CdO. Glass can be ground to provide powder-sized particles (in one embodiment, the powder size is from 2-6 microns) in a ball mill.

The glasses described herein are produced by conventional glass making techniques. For example, the glasses may be prepared as follows. For preparation of 500 -2000 gram quantities of glass frit, the ingredients were weighed then mixed in the desired proportions and heated in a bottom-loading furnace to form a melt in platinum alloy crucibles. Heating temperatures depend on the materials and can be conducted to a peak temperature (1100-1400°C) and for a time such that the melt becomes entirely liquid and homogeneous. The glass melts were quenched by a counter rotating stainless steel roller to form a 10-20 mil thick platelet of glass. The resulting glass platelet was then milled to form a powder with its 50% volume distribution set between 2 - 5 microns, though the particle size can vary depending on the final application of the encapsulation assembly. The glass powders were then formulated with filler and organic medium into a thick film composition (or "paste"). The glass powder is present in the glass frit composition in the amount of about 5 to about 76 wt. %, based on total composition comprising, glass and organic medium. In one embodiment, the organic medium contains water. In one embodiment, the organic medium includes an ester alcohol.

The organic medium in which the glass is dispersed is comprised of the organic polymeric binder which is dissolved in a volatile organic solvent and, optionally, other dissolved materials such as plasticizers, release agents, dispersing agents, stripping agents, antifoaming agents and wetting agents.

The solids can be mixed with an organic medium by mechanical mixing to form a pastelike composition, called "pastes", having suitable consistency and rheology for printing. A wide variety of liquids can be used as organic medium and water may be included in the organic medium. The organic medium must be one in which the solids are dispersible with an adequate degree of stability. The rheological properties of the medium must be such that they lend good application properties to the composition. Such properties include: dispersion of solids with an adequate degree of stability, good application of composition, appropriate viscosity, thixotropy, appropriate wettability of the substrate and the solids, a good drying rate, good firing properties, and a dried film strength sufficient to withstand rough handling. In one embodiment the organic medium comprises a suitable polymer and one or more solvent.

In certain embodiments, the polymer used in the organic medium is selected from the group consisting of ethyl cellulose, ethylhydroxyethyl cellulose, wood rosin, mixtures of ethyl cellulose and phenolic resins, polymethacrylates of lower alcohols, and monobutyl ether of ethylene glycol monoacetate or mixtures thereof

The most widely used solvents found in thick film compositions are ethyl acetate, and terpenes such as alpha- or beta-terpineol or mixtures thereof with other solvents such as kerosene, dibutylphthalate, butyl carbitol, butyl carbitol acetate, hexylene glycol and high boiling alcohols and alcohol esters, including isobutyal alcohol and 2-ethyl hexanyl. In addition, volatile liquids for promoting rapid hardening after application on the substrate can be included in the vehicle. In one embodiment, medium is selected from ethylcellulose and β-terpineol. Various combinations of these and other solvents are formulated to obtain the viscosity and volatility requirements desired. Water may be used as well as part of the organic medium.

The ratio of organic medium in the thick film composition to the glass frit solids in the dispersion is dependent on the method of applying the paste and the kind of organic medium used, and it can vary. Usually, the dispersion will contain 50-80 wt. % of glass frit and 20-50 wt. % of vehicle in order to obtain good coating. Within these limits, it is desirable to use the least possible amount of binder vis-à-vis solids in order to reduce the amount of organics which must be removed by pyrolysis and to obtain better particle packing which gives reduced shrinkage upon firing. The content of the organic medium is selected to provide suitable consistency and rheology for casting, printing, such as screen printing or ink-jet printing, molding, stencil printing, extruding, or coating by spraying, brushing, syringe-dispensing, doctor blading, and the like.

In the case of screen-printing, the screen mesh size controls the thickness of deposited material. In one embodiment, the screen used in screen printing has a mesh size of from 25 to 600; in one embodiment, the mesh size is from 50 to 500; in one embodiment, the mesh size is 200 – 350; in another embodiment the mesh size is from 200 to 275; and in another embodiment the mesh size is from 275 to 350. For reference purposes mesh sizes can have varying wire sizes that can alter the film formed during the printing process. A smaller mesh size results in thinner deposition as does a large screen wire size.

For reference purposes, with respect to screen mesh sizes, the following table is provided. Two of classifications for screen mesh sizes r are the US Sieve Series and Tyler Equivalent, sometimes called Tyler Mesh Size or Tyler Standard Sieve Series. The mesh opening sizes for these scales are given in the table below and provide an indication of particle sizes. The mesh number system is a measure of how many openings there are per linear inch in a screen. US sieve sizes differ from Tyler Screen sizes in that they are arbitrary numbers.

US Sieve Size	Tyler Equivalent	Opening mm	Opening in
-	2½ Mesh	8.00	0.312
-	3 Mesh	6.73	0.265
No. 3½	3½ Mesh	5.66	0.233
No. 4	4 Mesh	4.76	0.187
No. 5	5 Mesh	4.00	0.157
No. 6	6 Mesh	3.36	0.132
No. 7	7 Mesh	2.83	0.111
No. 8	8 Mesh	2.38	0.0937
No.10	9 Mesh	2.00	0.0787
No. 12	10 Mesh	1.68	0.0661
No. 14	12 Mesh	1.41	0.0555
No. 16	14 Mesh	1.19	0.0469
No. 18	16 Mesh	1.00	0.0394
No. 20	20 Mesh	0.841	0.0331
No. 25	24 Mesh	0.707	0.0278
No. 30	28 Mesh	0.595	0.0234
No. 35	32 Mesh	0.500	0.0197
No. 40	35 Mesh	0.420	0.0165
No. 45	42 Mesh	0.354	0.0139
No. 50	48 Mesh	0.297	0.0117
No. 60	60 Mesh	0.250	0.0098
No. 70	65 Mesh	0.210	0.0083
No. 80	80 Mesh	0.177	0.0070
No.100	100 Mesh	0.149	0.0059
No. 120	115 Mesh	0.125	0.0049
No. 140	150 Mesh	0.105	0.0041
No. 170	170 Mesh	0.088	0.0035
No. 200	200 Mesh	0.074	0.0029
No. 230	250 Mesh	0.063	0.0025
No. 270	270 Mesh	0.053	0.0021
No. 325	325 Mesh	0.044	0.0017
No. 400	400 Mesh	0.037	0.0015

NOTE: Source of Table is AZoM.com

The deposited glass frit composition is dried to remove volatile organic medium and solidify. Solidification can be carried out by any conventional means. In one embodiment, the composition is heated in an oven at about 100-120°C, though the temperature may vary depending on the softening point of the glass used and the type of getter material used, (if one is used). Furthermore, other techniques may be used to heat the glass frit without substantially heating the barrier sheet. The solidified material is then densified as desired. For example, densification can be carried out by any conventional means and may be done as part of one heating cycle immediately after the solidification heating or may be accomplished two or more separate heating cycles, with or without some degree of cooling between heatings. In some embodiments, the glass frit composition is densified when heated at 400- 650°C in a standard thick film conveyor belt furnace or in a box furnace with a programmed heating cycle forming a fired article.

When glass is used to create the barrier structure, the final thickness of the barrier structure formed from the glass frit composition can vary depending on the method of deposition, content of glass and solid % in the composition.

In one embodiment, the barrier material is a glass fiber. The glass fiber can be positioned on the barrier sheet and then heated to fuse and adhere it to the barrier sheet, again forming a glass structure. Any of the glass compositions discussed above can be used for the glass fiber.

In one embodiment, the barrier material is a metal. Almost all metals have the requisite low permeability to gases and moisture. Any metal can then be used, so long as it is stable to the atmosphere and adheres to the barrier sheet. In one embodiment, the metal is selected from Groups 3-13 in the Periodic Table. The IUPAC number system is used throughout, where the groups from the Periodic Table are numbered from left to right as 1-18 (CRC Handbook of Chemistry and Physics, 81st Edition, 2000). In one embodiment, the metal is selected from Al, Zn, In, Sn, Cr, Ni, and combinations thereof.

The metal can be applied by any conventional deposition technique. In one embodiment, the metal is applied by vapor deposition through a mask. In one embodiment, the metal is applied by sputtering.

The barrier material can be applied as one layer, or it can be applied as more than one layer to achieve the desired thickness and geometry. For example, a glass frit composition can be applied in multiple layers by successive screen-printing steps. The compositions in different layers can be the same or different.

In one embodiment, the barrier structure is created by using a suitable barrier material applied in a continuous manner without breaks. In the alternative, one more barrier structure can be created varying its the locations on the surface of the barrier sheet, and such multiple structure may optional have breaks in the barrier structure pattern (i.e., not a one continuous feature around the entire active area of the device) as necessary.

Although, it is three-dimensional, the perimeter appears as a line of material around the outer part of the major surface of the barrier sheet, or can be placed to merely be around the perimeter of the active area of the device. It has no gaps or openings and defines the area of the barrier sheet that will be sealed to the substrate of the electronic device. In one embodiment, encapsulation assembly is configured so that the barrier structure does not come into direct contact with the substrate of the device when the device is sealed.

In one embodiment, the barrier sheet comprises glass. Most glasses have a permeability of less than about 10^{-10} g/m^2/24 hr/atm. In one embodiment, the glass is selected from borosilicate glasses and soda lime glass. In one embodiment, the barrier sheet is substantially planar. In one embodiment, the barrier sheet has a substantially planar outer edge with a shaped interior. In one embodiment, the barrier sheet is rectangular. In one embodiment, the barrier sheet has a thickness in the range of 0.1mm to 5.0mm.

In one embodiment, as shown in Fig. 1, the perimeter 2 has a rectangular shape around the outer edge of barrier sheet 1, as in a window frame. In one embodiment, the perimeter of barrier material has a circular shape. In one embodiment, the perimeter of barrier material has an irregular shape adapted to complement the particular substrate of the electronic device.

The barrier structure itself can have different geometries. The edges can be straight, tapered, or curved. The top can be flat or beveled. In one embodiment, the geometry of the top of the barrier structure is designed to engage with its complement in relevant section of the substrate. For example, they can be joined in a tongue and groove arrangement.

The barrier structure can have any width and thickness that will provide protection from contaminants such as hydrogen and oxygen gases and moisture and the requirements of the device or other application on which the encapsulation assembly is to be used. In one embodiment, the barrier structure has a width in the range of 10 to 5000 microns and a thickness in the range of 5 to 500 microns. In one embodiment, the barrier structure is about 7 microns thick. In one embodiment, the barrier structure has a width in the range of 500 to 2000 microns and a thickness in the range of 50 to 100 microns. The thickness may be achieved through the use of more than one structure.

In one embodiment, two or more continuous deposited patterns (e.g., around the perimeter of the active area of the device) of the barrier structure material are applied to form two or more structures on the barrier sheet. The materials used to create the structures can be the same or different in and the shape and dimensions of the structures can be the same or different. In one embodiment, the structures from the barrier sheet are the made from the same materials and have the same shape.

To use the encapsulation assembly, at least one adhesive is applied to the barrier structure (s), barrier sheet, substrate of the electronic device, or any combination of these. If the adhesive is applied to the substrate of the electronic device only, then it must be deposited in a manner so as to so that the substrate and the barrier sheet can be coupled together. In one embodiment, the adhesive is applied to the bottom and outer edge of the barrier structure. In another embodiment, the adhesive is applied to the substrate of the electronic device. Selection of the adhesive is made by consideration of whether it will adhere the barrier structure to the device substrate, or if the barrier structure is on the device substrate, then the adhesive must bond the barrier structure to the barrier sheet.

Advantages of certain embodiments can be appreciated. That is, though use of a properly designed barrier structure, it is possible to use a smaller amount of adhesive than would otherwise be necessary. In addition, it is possible to make a selection of one or more adhesives from a larger number of adhesive compositions because of the smaller area where the adhesive contaminant permeation rate is relevant.

In one embodiment, when glass barrier structures are used, the adhesive is a UV curable epoxy. Such materials are well known and widely available. Other adhesive materials can be used so long as they have sufficient adhesive and mechanical strength.

In one embodiment, provided is an electronic having the barrier sheet with a barrier structure encapsulation assembly adhered thereto by application of a suitable adhesive to the substrate of the electronic device. The other properties of the substrate are governed primarily by the requirements of the electronic device. For example, for organic light emitting diode display devices, the substrate is usually transparent so that it transmits the light generated. The substrate can be made of materials which can be rigid or flexible and includes, for example, glass, ceramic, metals, polymeric films, and combinations thereof. In one embodiment, the substrate comprises glass. In one embodiment, the substrate is flexible. In one embodiment, the substrate comprises polymeric films.

In one embodiment, to use the encapsulation assembly is placed over the substrate of the electronic device. This assembly step can be done in normal ambient conditions or may be done under controlled conditions including reduced pressure or inert atmospheres as desired or required by the electronic device to which it is applied.

In one embodiment, the barrier sheet also has a getter material applied thereto. In one embodiment, the getter material is deposited on the surface of the barrier sheet so as to be between the barrier structure and the active area of the device when assembly of the device is completed. Optional additional locations of gettering materials may be deposited as desired.

The getter material can be in the form of a frit, pellet, wafer or a film. In one embodiment, a getter material is applied to the barrier sheet as part of a thick film paste composition, as disclosed in co-pending applications US Ser. No. 10/712670 and US Provisional No. 60/519139. In one embodiment, at least a portion of the getter material is deposited outside of the device active area so as to create a cavity above the active area in the device when the encapsulation assembly is used with the device.

In an embodiment where the getter material is deposited on the barrier sheet, the getter material can be optionally activated in a separate step from the manufacture of the encapsulation assembly itself and before the encapsulation assembly is applied to the device. Thusly, the encapsulation assembly can be stored for long periods of time under ordinary storage conditions, as the getter material may activated at a later time when the encapsulation assembly is used in the manufacture of the device. In such embodiments, once the getter material is activated, the encapsulation assembly can be maintained in a controlled environment and in such a manner so that the getter material's performance capacity is not consumed prematurely.

In one embodiment, improved device lifetime have been observed with an encapsulation assembly shown in Figure 28 is used to encapsulate an organic light emitting diode display device.

EXAMPLES

The following examples illustrate the use of glass as the structure material applied to a glass barrier sheet for use as the encapsulation assembly for an organic light emitting diode display.

Examples 1-3

A series of silicate glass compositions that have been found to be suitable as the barrier material in the new method are shown in Table 1. All glasses were prepared by mixing raw materials and then melting in a platinum crucible at 1100-1400°C. The resulting melt was stirred and quenched by pouring on the surface of counter rotating stainless steel rollers or into a water tank. The glass powders prepared for the invention were adjusted to a 2-5 micron mean size by wet or dry milling using alumina ball media prior to formulation as a paste. The wet slurry after milling was dried in a hot air oven and deagglomerated by the sieving process.

TABLE 1
Glass composition in weight %

Ex. #	1	2	3
SiO_2	7.1	15.8	14.81
Al_2O_3	2.1	2.6	0.82
Bi_2O_3	69.8	81.6	
B_2O_3	8.4		11.83
CaO	0.5		
ZnO	12.0		6.58
PbO			65.96

Examples 4-6

Glass frit compositions were prepared by mixing glass with organic media based on the mixture of Texanol® solvent (an ester alcohol (2,2,4, trimethyl 1,3 pentanediol monoisobutyrate) sold by Eastman Chemical Co.) and ethyl cellulose resin. Table 2 represents the examples of compositions. Changing the content of solvent can be used to adjust paste viscosity and film thickness for different deposition methods.

The glass frit composition was printed using a 200 mesh screen on a glass sheet based on soda-lime silicates, dried at 120°C for solvent evaporation, and then fired at a peak temperature of 450-550°C for 1-2 hours in a box furnace, to form a glass structure on the glass sheet.

Some samples were also processed at 550°C for 1 hour using a conveyor furnace with a heating/cooling profile of 3-6 hours. The printing/firing step was repeated to generate thicker structures when needed. The fired thickness of single-printed glass structure ranged from 10 micron to 25 micron, depending on paste viscosity and screen mesh size.

The printed glass frit composition fired dense and showed good adhesion with the glass sheet. No cracking or blistering was observed on the surface of fired structure s. The thickness uniformity of the barrier structures after firing was kept within +/- 2 micron regardless of paste composition.

TABLE 2
Compositions used to Screen Print the a Glass Barrier Structures
composition in weight %

Ex. #	4	5	6
Glass. #	1	1	1
Glass	79.1	78.3	76.0
Surfactant	0.4	0.4	0.4
Binder Resin	1.3	1.3	1.3
Solvent	19.2	20.0	22.3

Example 7

In this example, a coating of Barium metal was used to simulate the moisture and air-sensitivity of an electronic device.

A 300 Angstrom thick barium coating was deposited onto a .7mm thick glass substrate. This substrate was encapsulated using a glass frit barrier structure (1mm wide by 80 microns thick) made with glass #1 from Table 1 and fired onto a .7mm thick glass sheet as the barrier sheet. A UV curable epoxy was used to join the two sheets. Similar examples were prepared without the glass frit barrier structure. Visible observation indicated the samples made with the glass barrier structure protected the Barium film from the water and oxygen in air much better than the samples without the glass barrier structure. The visual observations were quantified by measuring and plotting the electrical resistance of the 300-Angstrom barium film between adjacent electrodes as a function of the time that the packages were subjected to a 60 DegC/90% RH environment. Water that permeated into the package through the epoxy seal would chemically react with the Barium coating resulting in different film resistance. As can be seen from the attached chart as Figure 29. This information illustrates that use of the getter material is optional.

CLAIMS

What is claimed is:

1. An encapsulation assembly for an electronic device, having a substrate and an active area, the encapsulation assembly comprising:

a barrier sheet; and

a barrier structure that extends from the sheet, wherein:

the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon when used in conjunction with an adhesive to bond the encapsulation assembly to the device substrate; and wherein the barrier structure is not fused to the device substrate.

2. The encapsulation assembly of claim 1, wherein the barrier structure comprises a barrier material selected from the group consisting of a glass, ceramic, metallic materials or combinations thereof.

3. The encapsulation assembly of claim 1, further comprising a getter material deposited on the barrier sheet and configured so as to be outside of the device active area, yet exposed to the device active area, when the device is bonded to the encapsulation assembly.

4. An encapsulation assembly for an electronic device, having a substrate which further has a sealing structure and an active area, the encapsulation assembly comprising:

a barrier sheet having a substantially flat surface; and

a barrier structure that extends from the flat surface, wherein:

the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon; and wherein the barrier structure is configured to engage with the sealing structure on the device substrate.

5. The assembly of claim 4 further comprising a getter material deposited on the barrier sheet and configured so as to be outside of the device active area when the device is bonded to the encapsulation assembly, yet exposed to the device active area.

6. The assembly of claim 4, wherein the barrier structure is configured to be in substantially direct contact with the seal structure on the device substrate.

7. The assembly of claim 1 or 4, further comprising an adhesive to the barrier structure and said adhesive deposited in a location and in an amount sufficient to bond the assembly to the device.

8. An encapsulation assembly for an electronic device comprising a barrier sheet having a substantially flat surface and a sealing structure

and wherein the sealing structure is configured to engage with a barrier structure on the substrate of the electronic device.

9. The assembly of claim 1 or 4, wherein the barrier structure comprises a glass material.

10. A seal for an electronic device, said electronic device having a substrate, the seal comprising:

a barrier structure; and

a heating element in contact with the barrier structure.

11. The seal of claim 10, wherein the heating element is disposed on a surface of an encapsulation assembly that is juxtaposed with the barrier structure and wherein after causing the heating element to heat the barrier structure, the barrier structure is fused to establish at least a portion of a hermetic seal between the encapsulation assembly and the device substrate.

12. The seal of claim 11, wherein after heating the heating element fuses the barrier structure to the encapsulation assembly and the device substrate.

13. An encapsulation assembly for an organic electronic device comprising:

a barrier sheet sized to cover anelectrically active area of an organic electronic device; and

a first keying structure, wherein:

the first keying structure is configured to be attached to a second keying structure of a substrate;

the second keying structure is a complement of the first keying structure; and

a combination the first and second keying structures are capable of forming at least part of a hermetic seal.

14. The encapsulation assembly of claim 13, wherein the encapsulation assembly is transparent.

15 .The encapsulation assembly of claim 14, wherein a shape of the first keying structure is substantially semi-circular shaped, triangular shaped, rectangular shaped, or frustum shaped.

16. The encapsulation assembly of claim 15, wherein the first keying structure comprises a substantially continuous engagement rib.

17. The encapsulation assembly of claim 16, further comprising a getter material, wherein the getter material is located along the surface and is configured to be exposed to the electronic active area.

18. An electronic device comprising:

a substrate comprising an electrically active area of an organic electronic device;

an encapsulation assembly covering the electrically active area, wherein the encapsulation assembly comprises a barrier surface that faces the device substrate; and

a barrier structure comprising a barrier material, wherein the barrier structure is attached to the barrier surface of the encapsulation assembly and the substrate, wherein the barrier structure is no more than 1 micorn away from device substrate.

19. The organic electronic device of claim 18, further comprising an adhesive that contacts the barrier structure and the device substrate.

20. The organic electronic device of claim 19, wherein the barrier material comprises a glass, ceramic, metallic, or a combination thereof.

21. The organic electronic device of claim 20, the encapsulation assembly further comprises a getter material exposed to the electronic active area.

22. An encapsulation assembly for an electronic device, having a substrate, having a barrier structure extending from the substrate and outside of an active area, the encapsulation assembly comprising:

a barrier sheet having a substantially flat surface and a sealing structure; and

a wherein the barrier street is configured to engage with the barrier structure on the device substrate.

23. A electronic device comprising the encapsulation assembly of claim 22.

24. A method for sealing an electronic device on a substrate, comprising:

forming an encapsulation assembly comprising a barrier sheet and a barrier structure that extends from the sheet;

applying adhesive to at least one of the barrier structure and the substrate; and

bonding the barrier structure to the substrate such that the electronic device is enclosed by the encapsulation assembly.

25. A method according to Claim 24, wherein the barrier structure comprises a hermetic material selected from glasses, ceramics, metals, metal oxides, metal nitrides, and combinations thereof.

26. A method according to Claim 25, wherein the barrier structure is formed from a glass frit composition.

27. A method according to Claim 26, further comprising solidifying and densifying the glass frit composition.

28. A method according to Claim 26 wherein said glass frit composition comprises a glass powder comprising at least one of PbO, Al_2O_3, SiO_2, B_2O_3, ZnO, Bi_2O_3, Na_2O, Li_2O, P_2O_5, NaF and CdO, and MO where O is oxygen and M is selected from Ba, Sr, Pb, Ca, Zn, Cu, Mg, and mixtures thereof.

29. An encapsulation assembly for an electronic device, having a substrate and an active area, the encapsulation assembly comprising:

a barrier sheet; and

a barrier structure that extends from a surface of the sheet, the barrier structure further including a heating element, wherein the barrier structure is configured so as to substantially hermetically seal an electronic device when in use thereon.

30. An encapsulation assembly according to Claim 1, 13, or 29 wherein the electronic device is selected from a light-emitting diode, a light-emitting diode display, a laser diode, a photodetector, photoconductive cell, photoresistor, photoswitch, phototransistor, electrochemical display, phototube, IR-detector, photovoltaic device, solar cell, light sensor, transistor, field emission displays, plasma displays, microelectrical mechanical systems, photonic, electronic devices using integrated circuits, accelerameter, gyroscope, motion sensor, or diode.

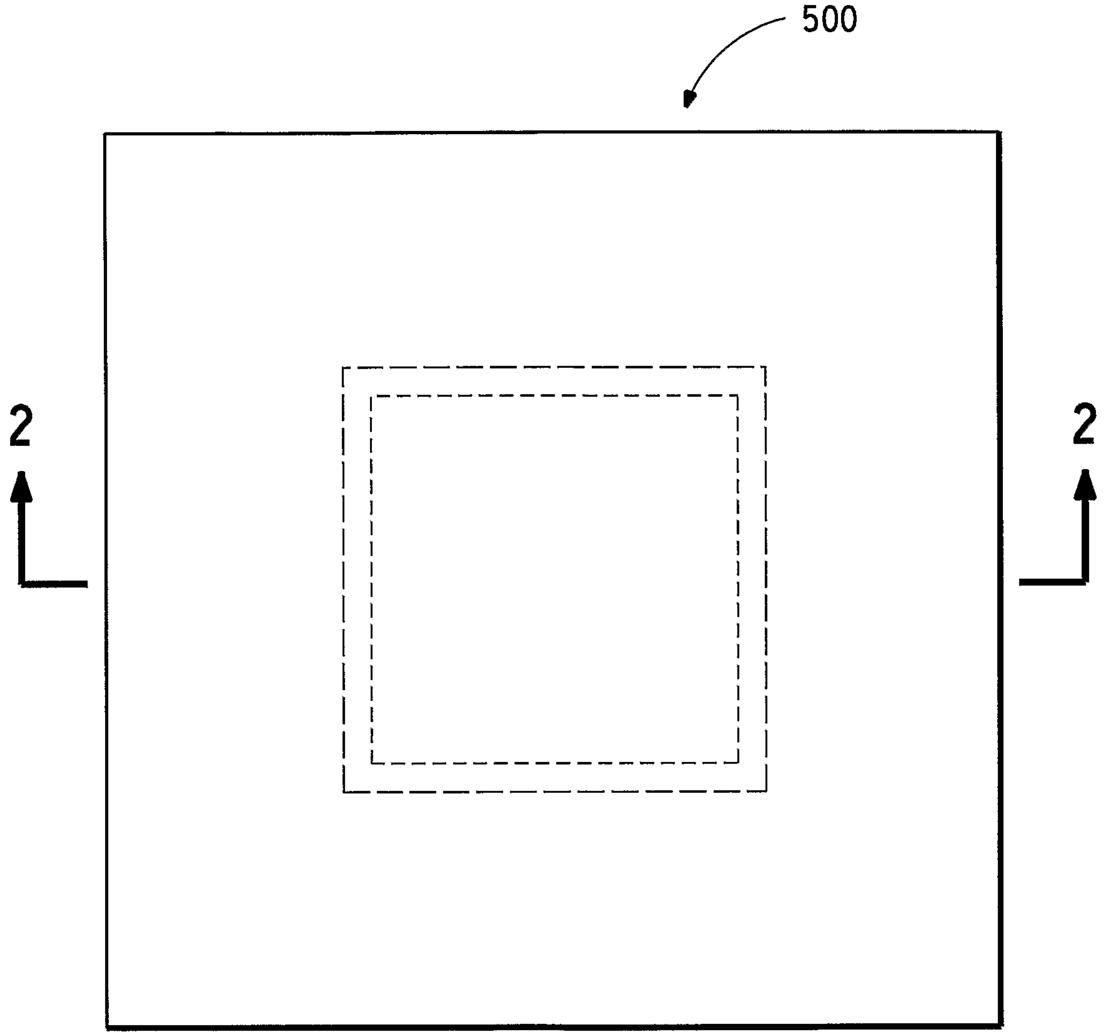


FIG. 1

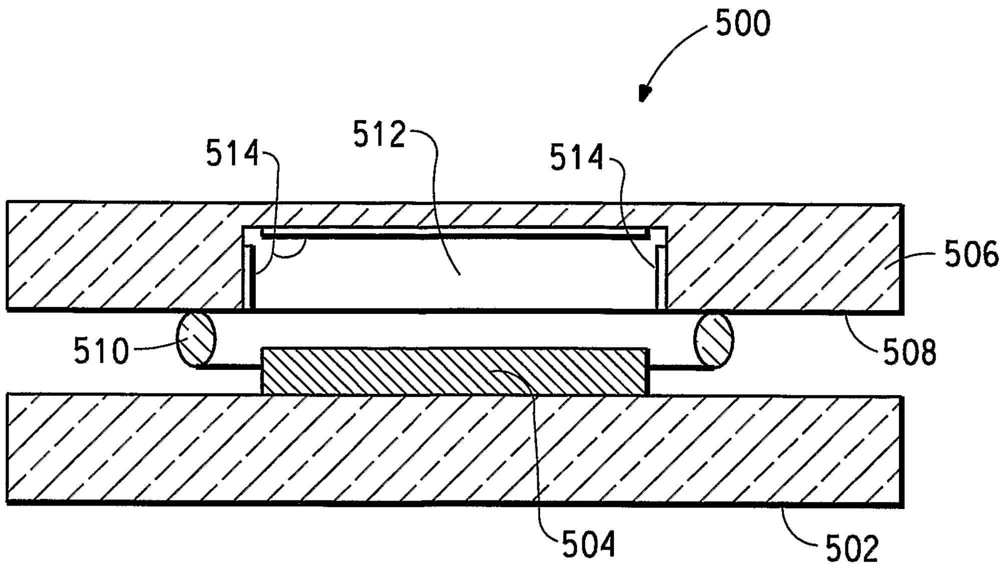

500
514
512
514
506
510
508
504
502

FIG. 2

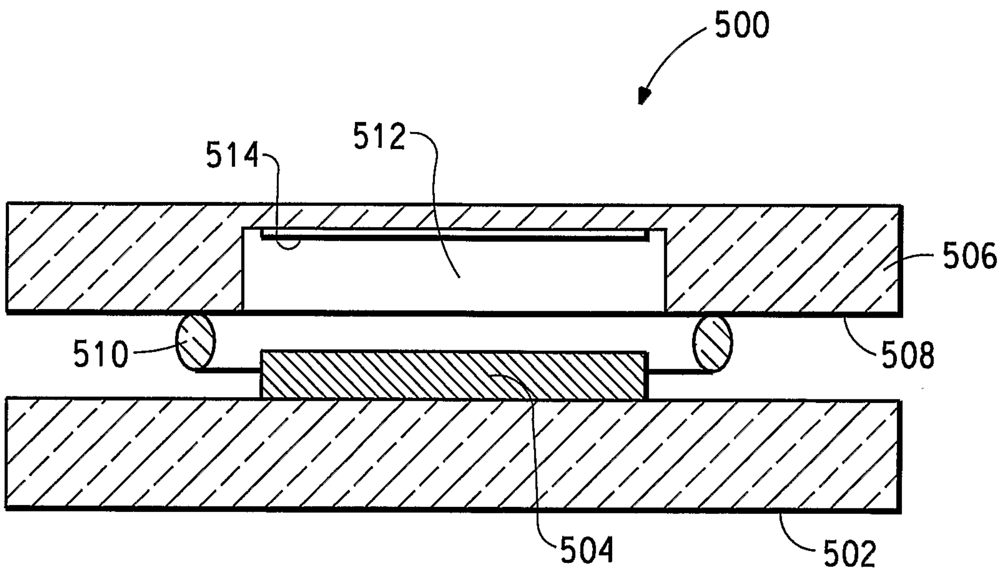

500
514
512
506
510
508
504
502

FIG. 3

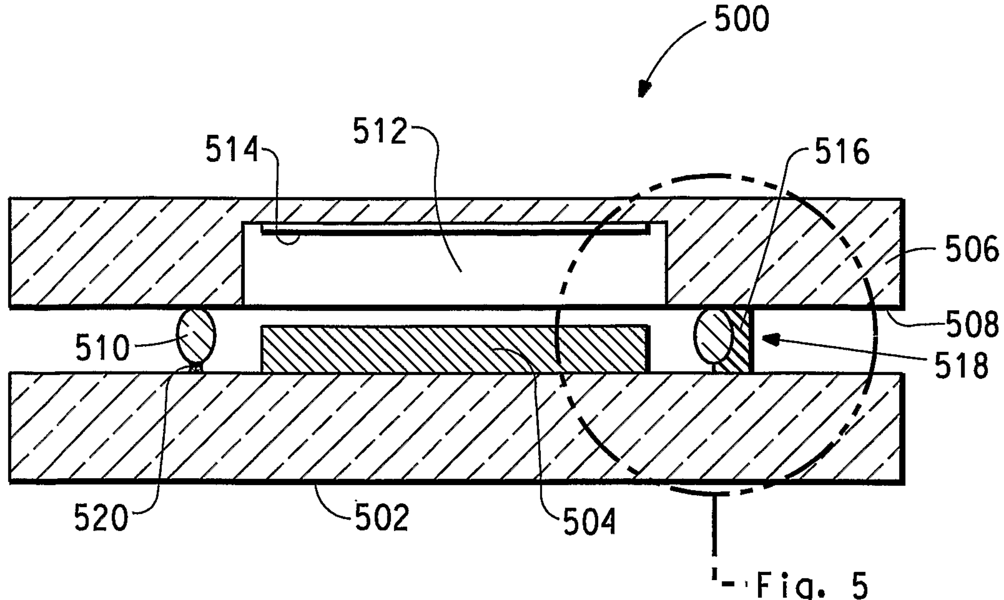

500
514
512
516
506
508
510
518
520
502
504
Fig. 5

FIG. 4

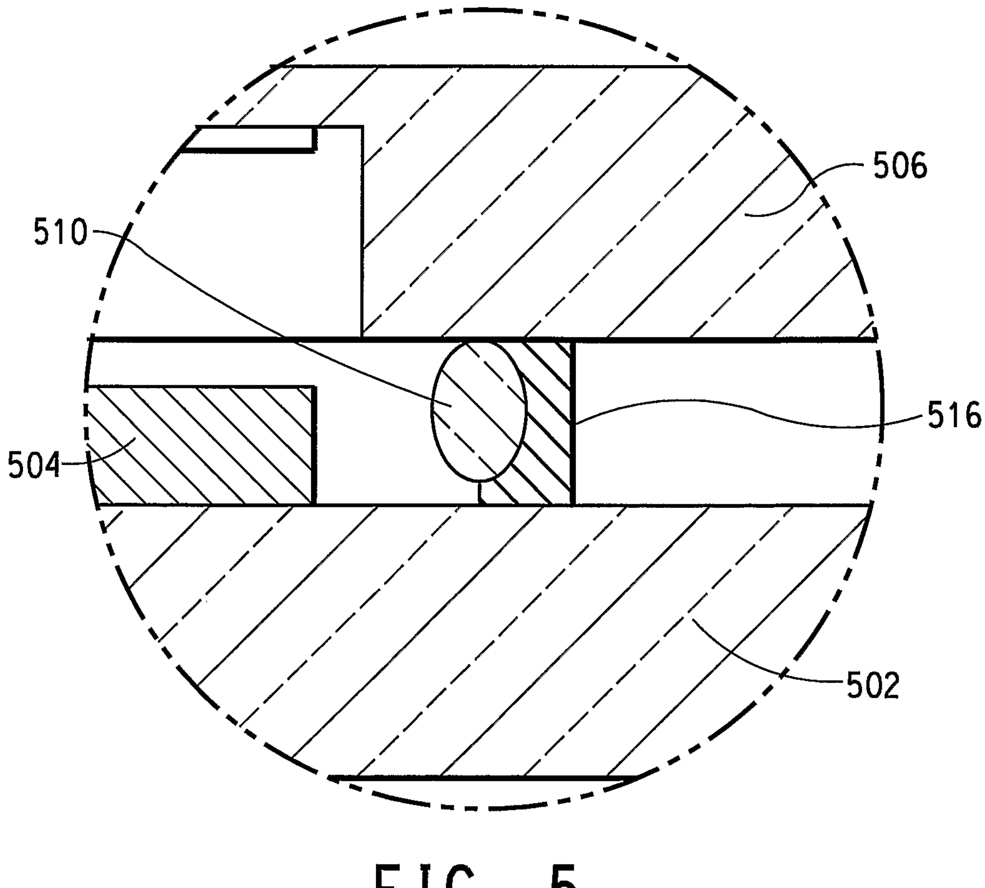

506
510
516
504
502

FIG. 5

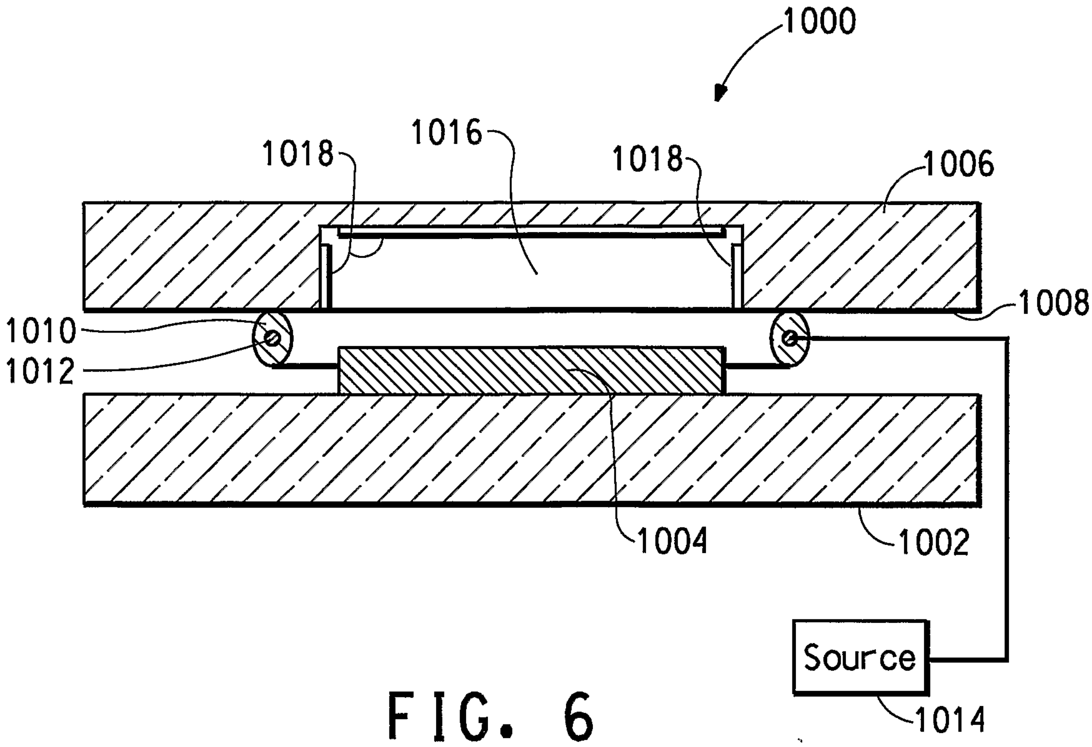

1000
1018
1016
1018
1006
1008
1010
1012
1004
1002
Source
1014

FIG. 6

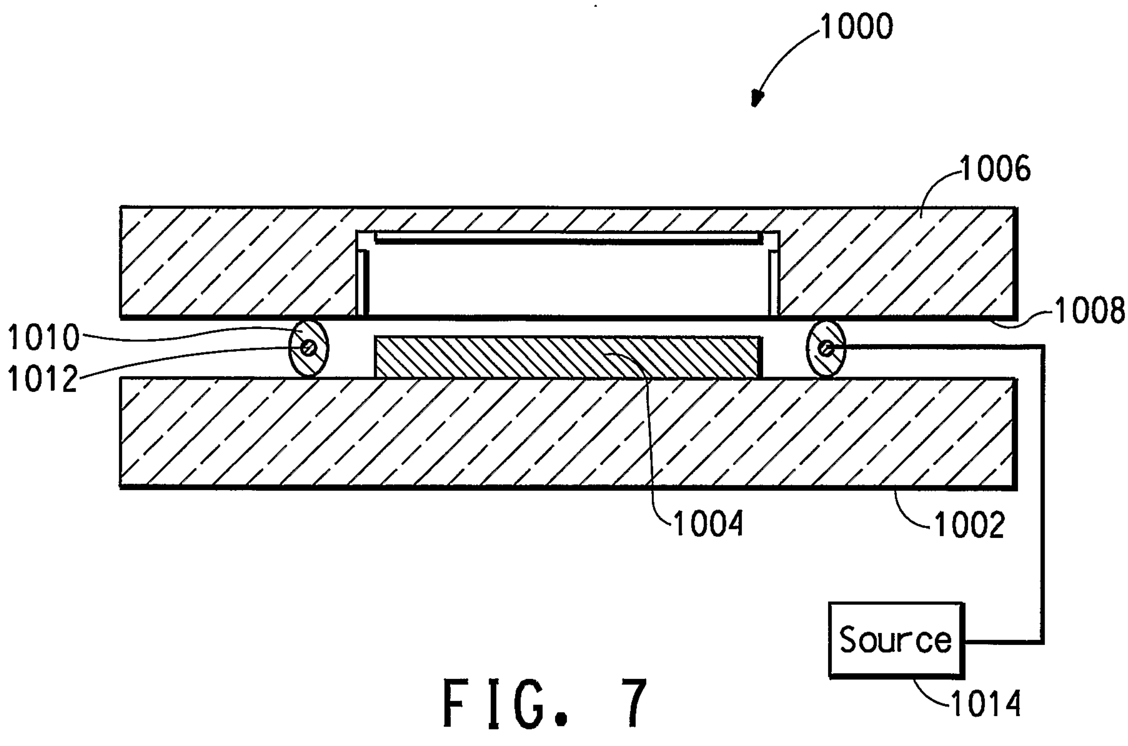

1000
1006
1008
1010
1012
1004
1002
Source
1014

FIG. 7

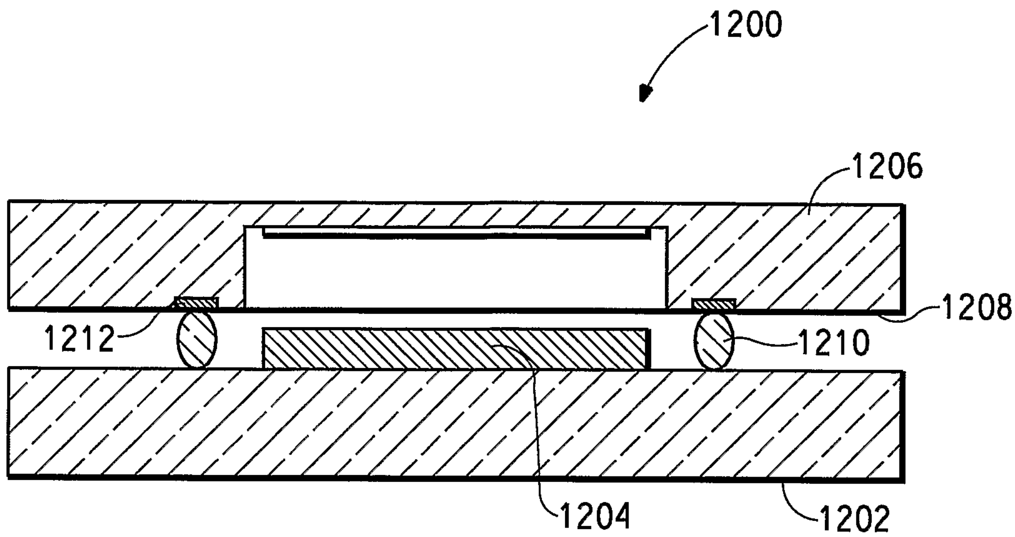

1200
1206
1208
1212
1210
1204
1202

FIG. 8

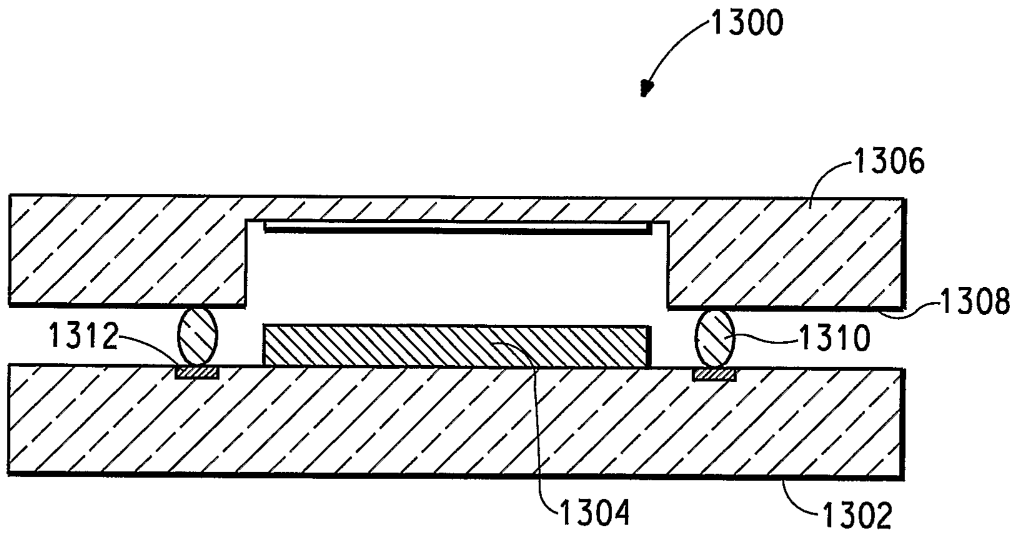

1300
1306
1308
1312
1310
1304
1302

FIG. 9

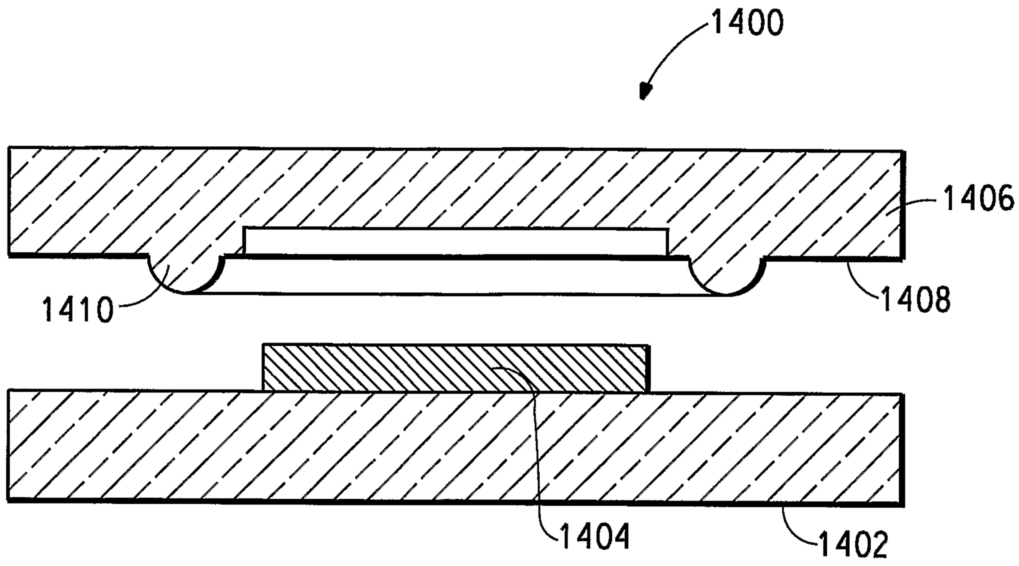

1400
1406
1410
1408
1404
1402

FIG. 10

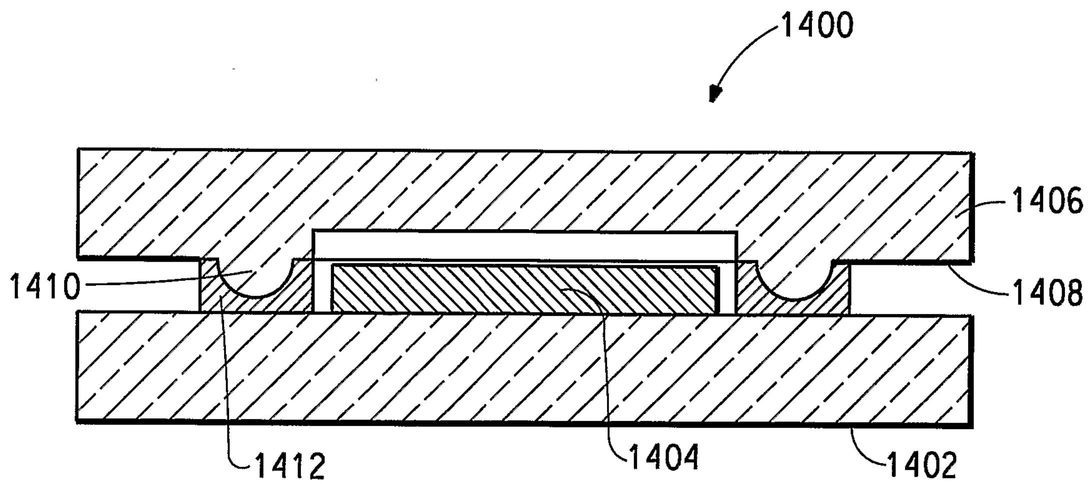

1400
1406
1410
1408
1412
1404
1402

FIG. 11

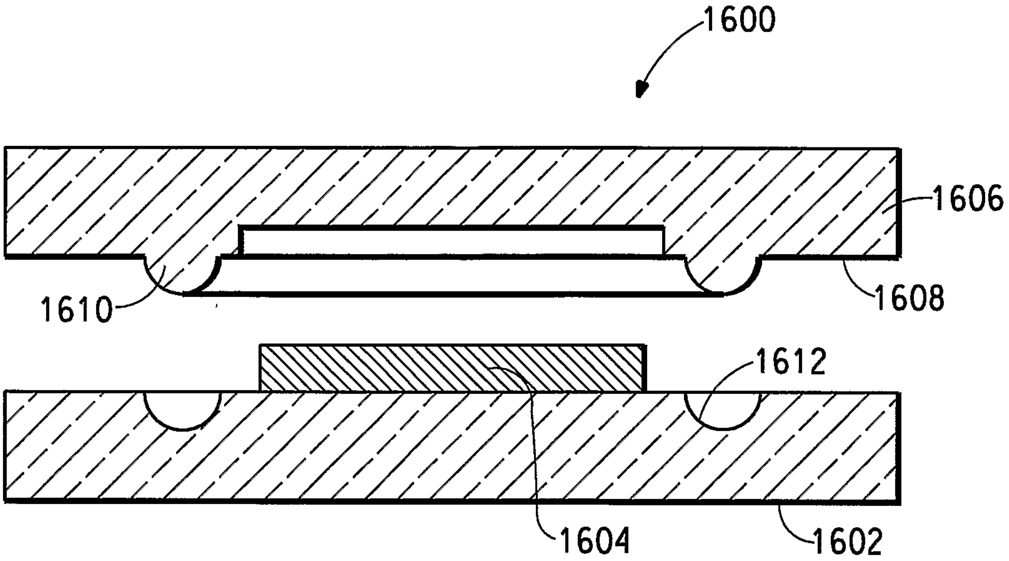

1600
1606
1610
1608
1612
1604
1602

FIG. 12

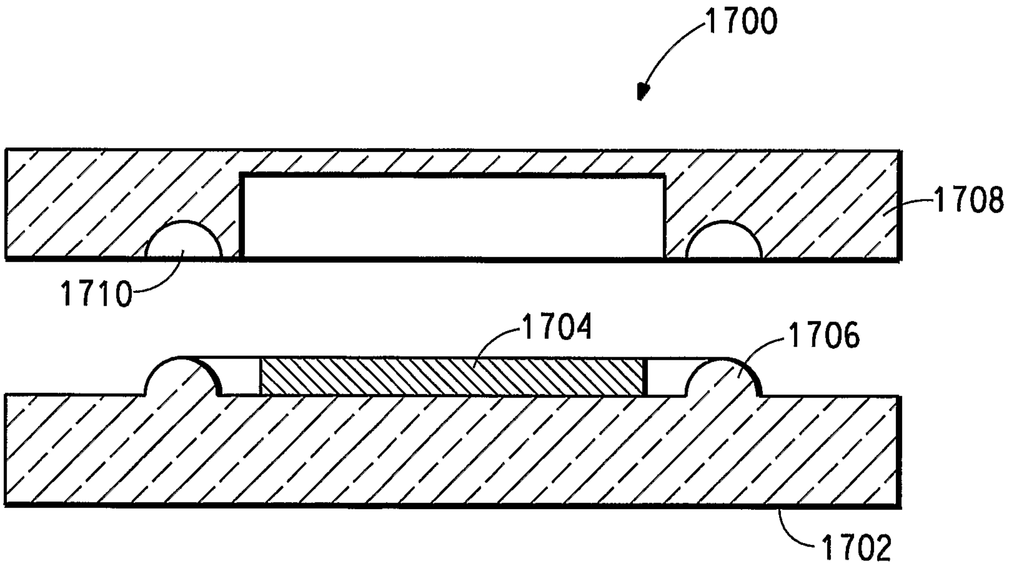

1700
1708
1710
1704
1706
1702

FIG. 13

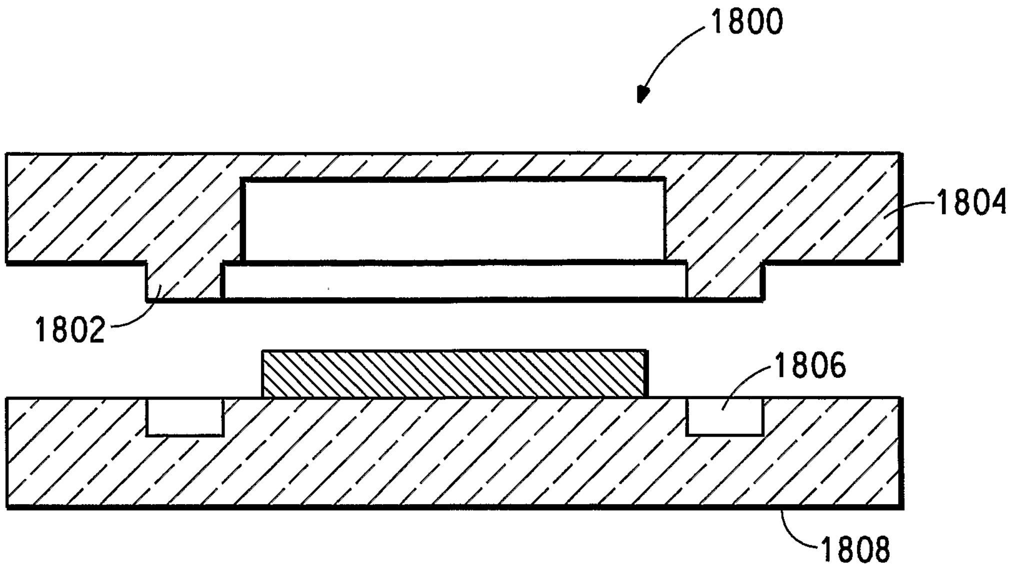


FIG. 14

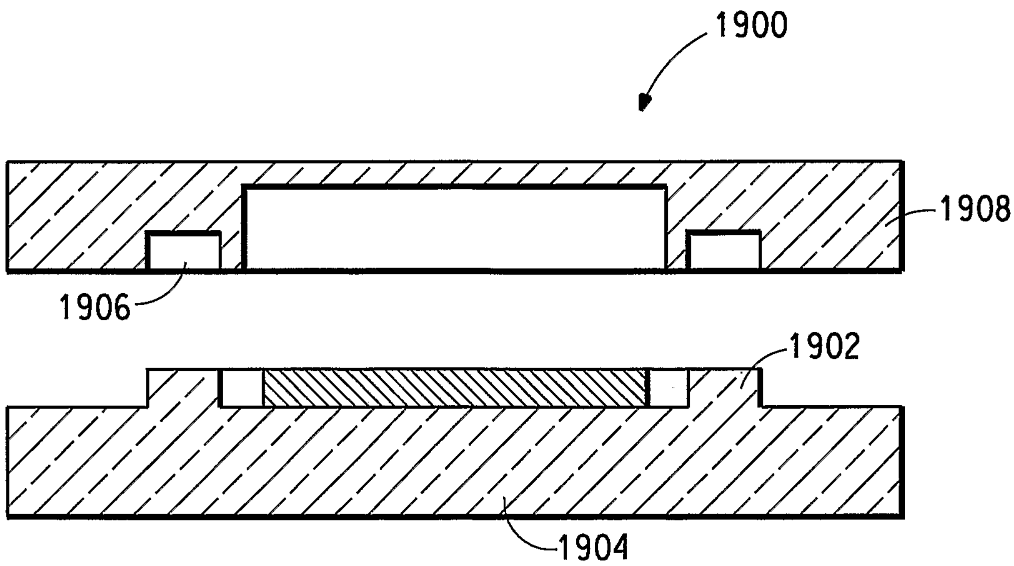


FIG. 15

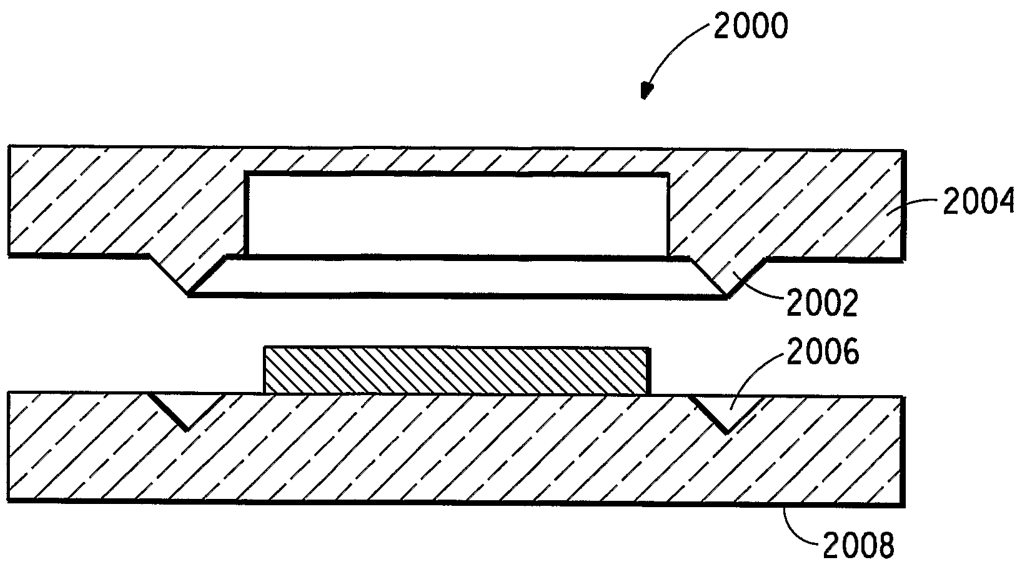


FIG. 16

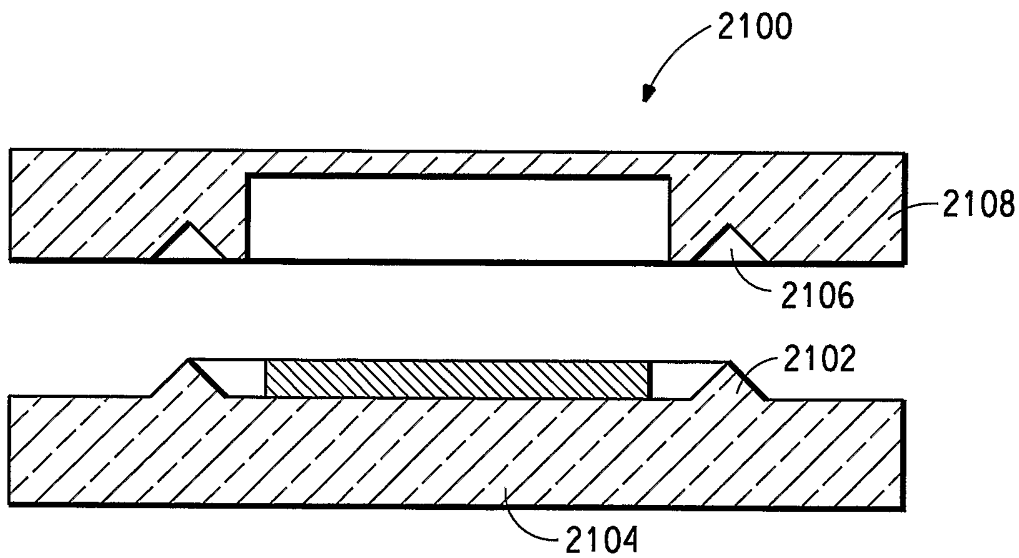


FIG. 17

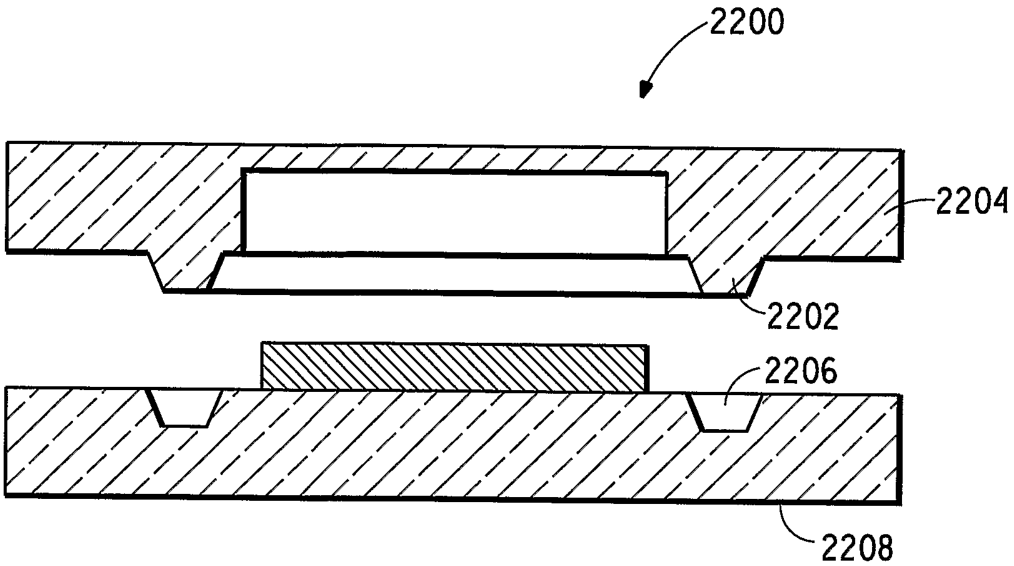


FIG. 18

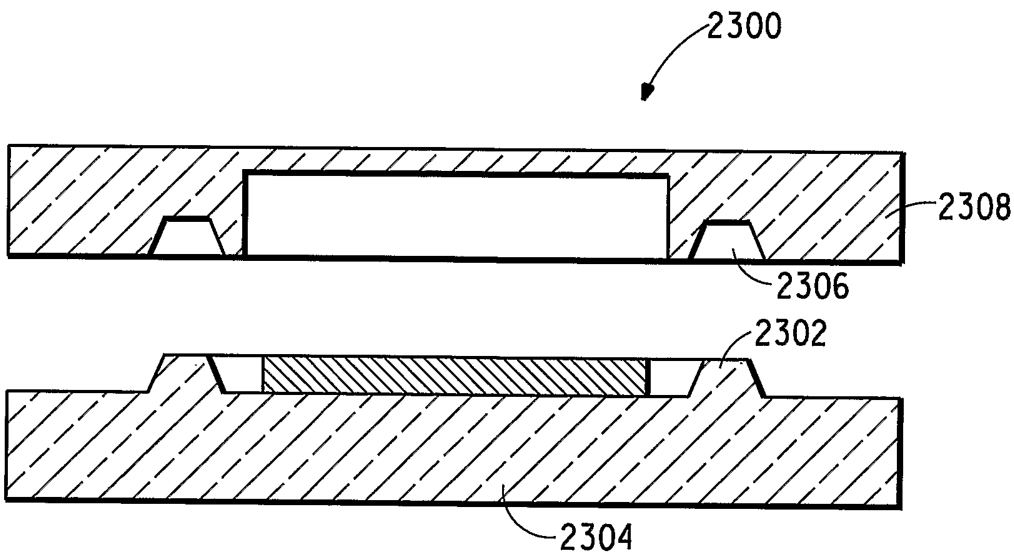


FIG. 19

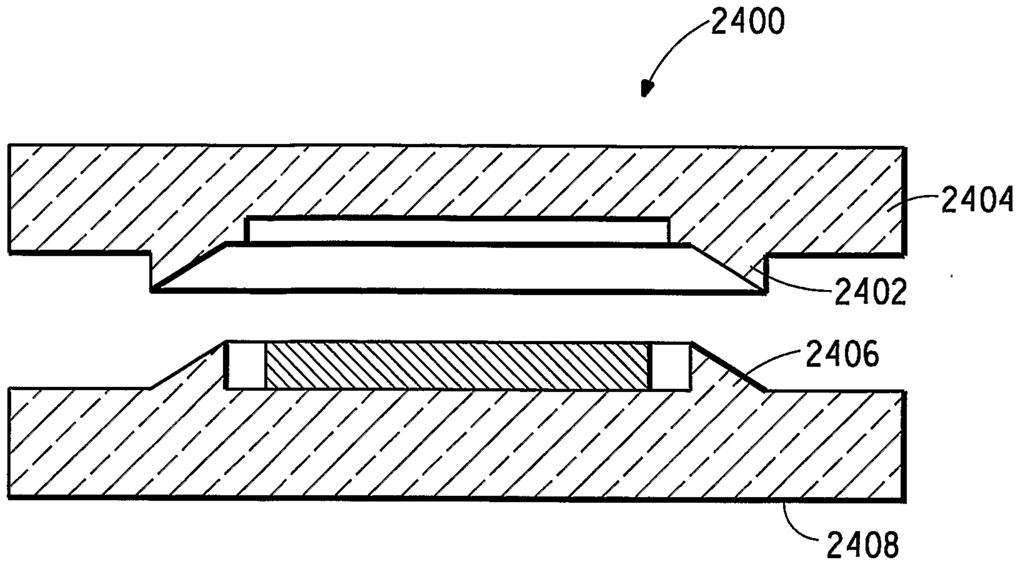


FIG. 20

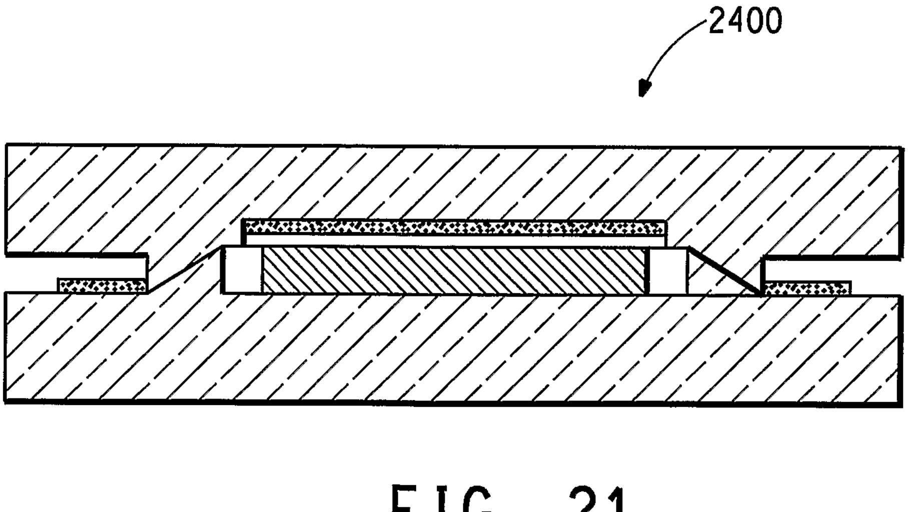


FIG. 21

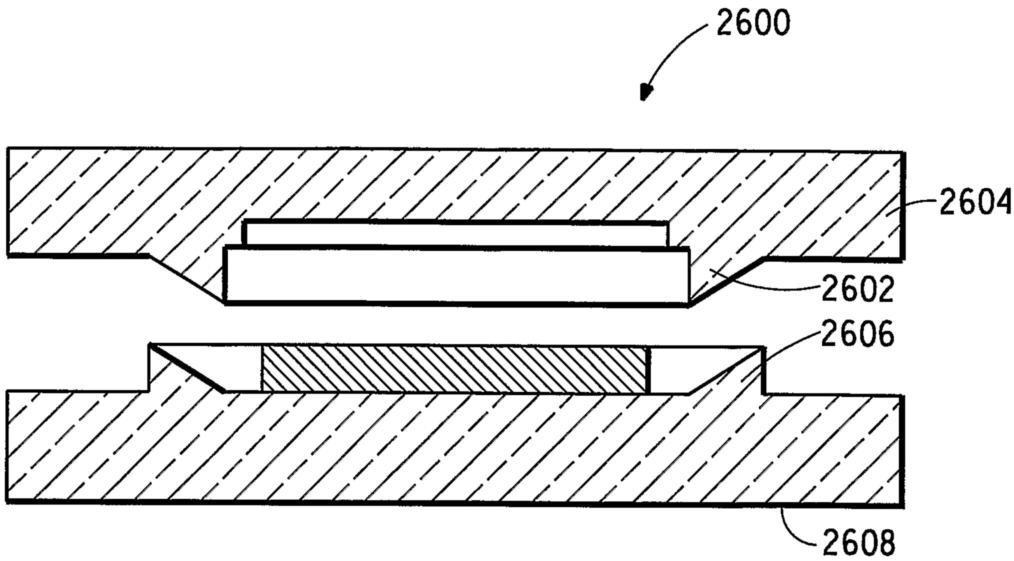


FIG. 22

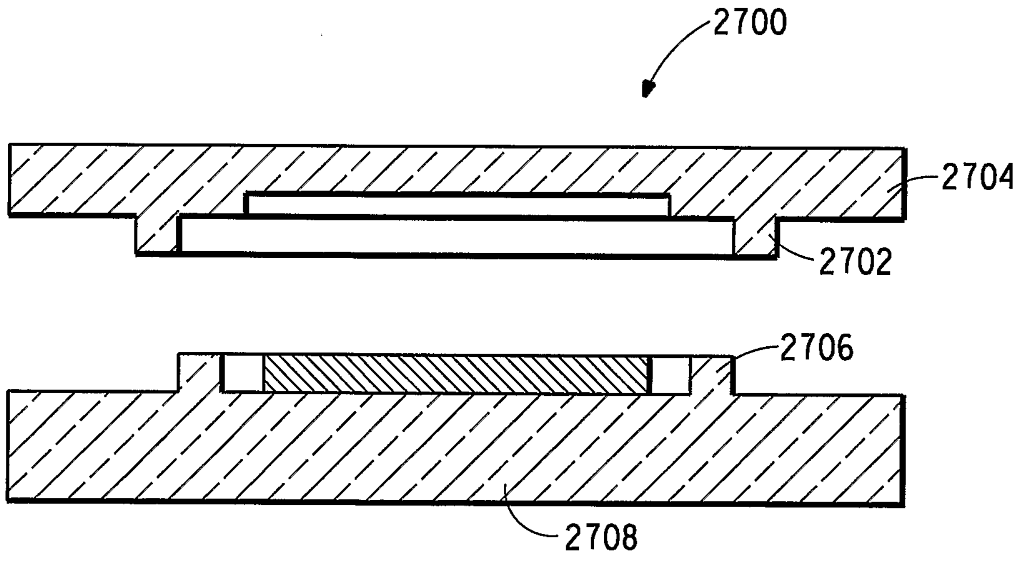


FIG. 23

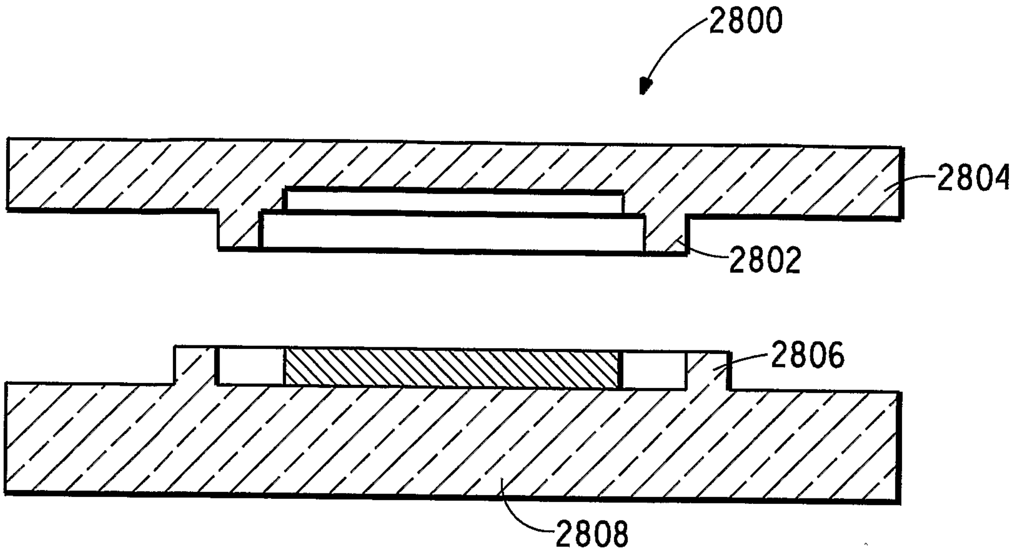


FIG. 24

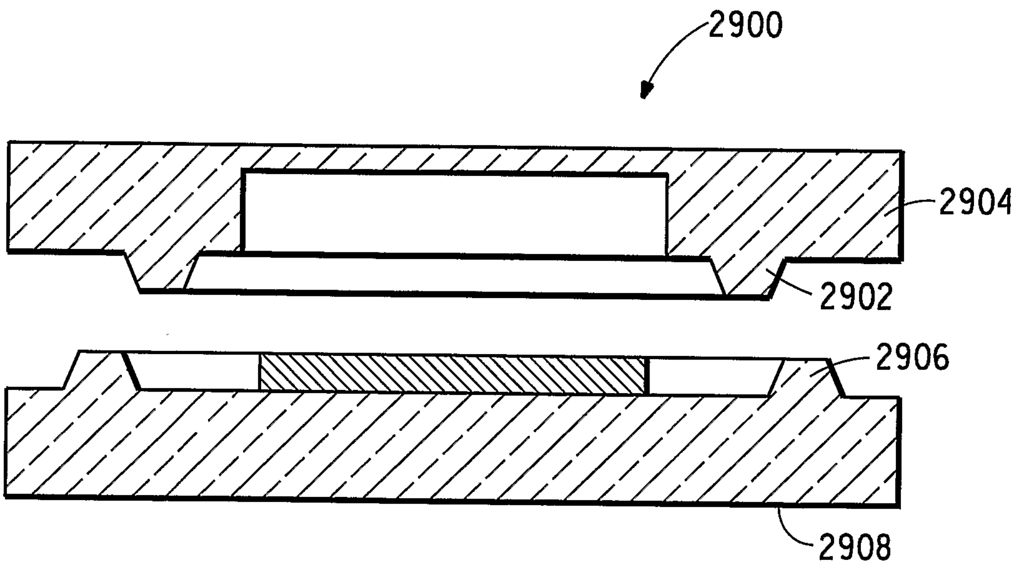


FIG. 25

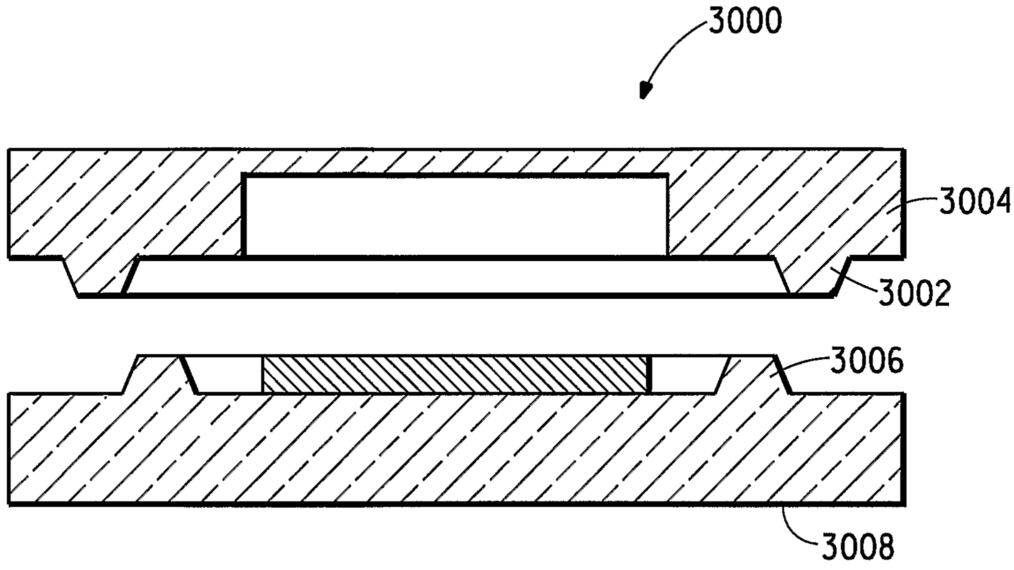


FIG. 26

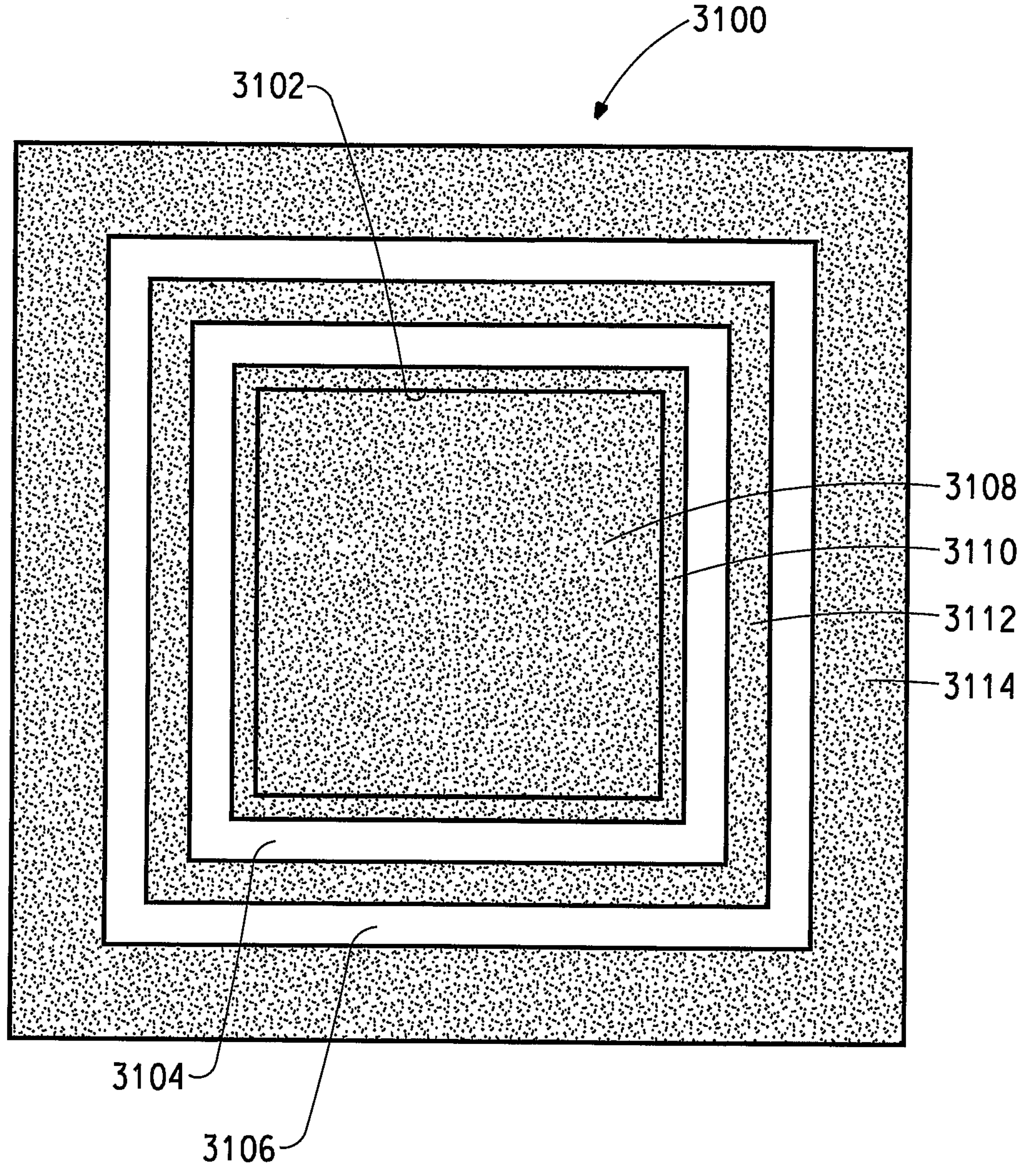


FIG. 27

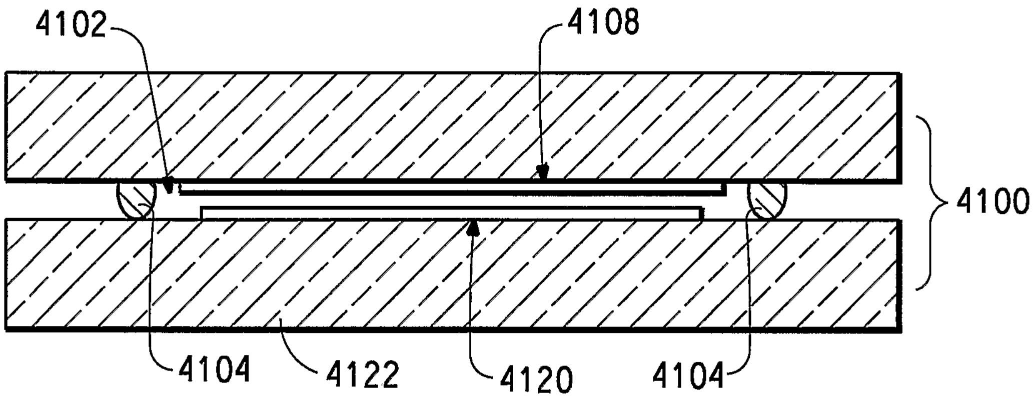


FIG. 28

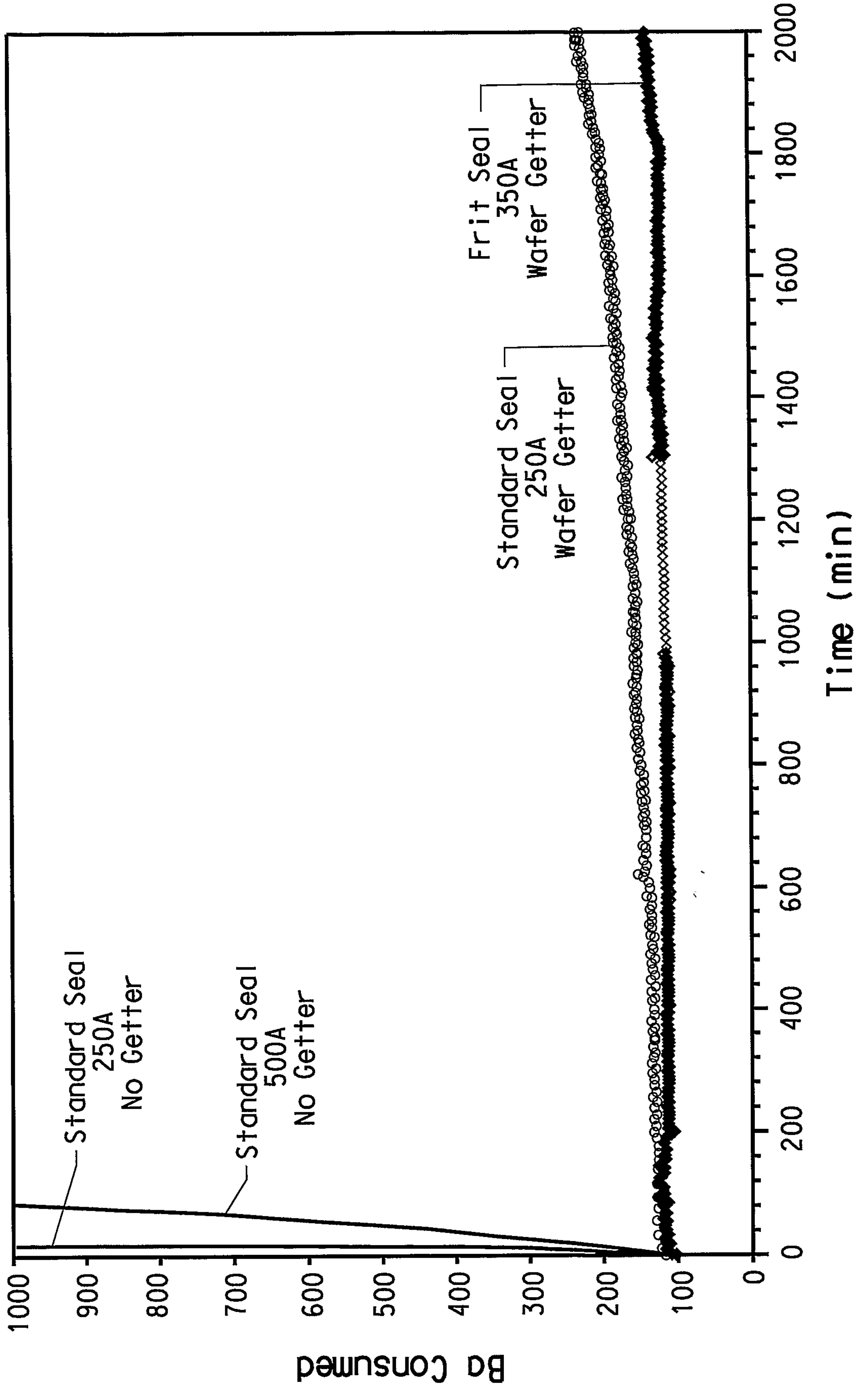

Standard Seal
250A
No Getter
Standard Seal
500A
No Getter
Standard Seal
250A
Wafer Getter
Frit Seal
350A
Wafer Getter
Ba Consumed
Time (min)
0
100
200
300
400
500
600
700
800
900
1000
0
200
400
600
800
1000
1200
1400
1600
1800
2000

FIG. 29